1956

# PETROLEUM REFINER

REFINING | PETROCHEMICALS | NATURAL GASOLINE

• *Special Report . . .*
Petrochemical Developments
Page 129

• Computers for Cooling Towers
Page 211

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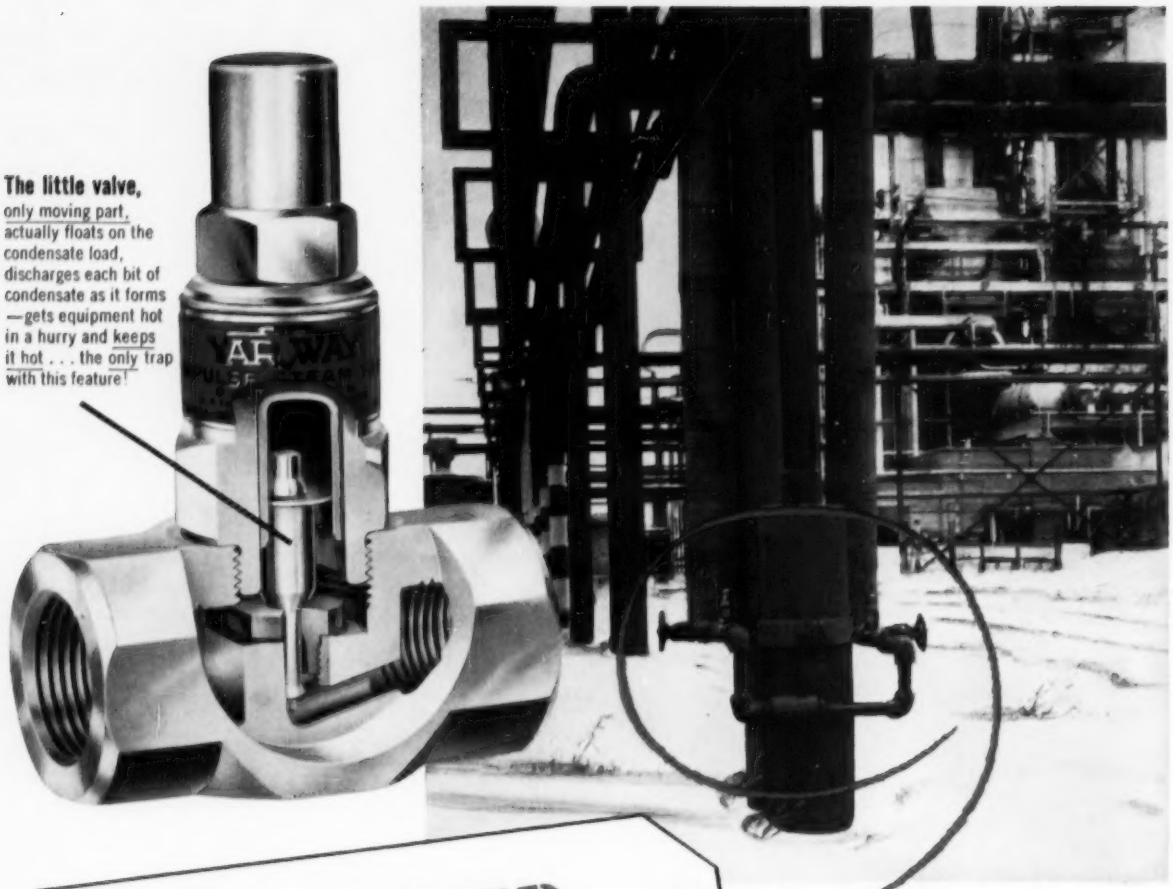


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Volume 35, No. 12 December, 1956

PETROLEUM REFINER
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## PETROCHEMICAL DEVELOPMENTS

Foreword ..... 131
Thomas C. Ponder
What's Ahead for Petrochemicals in '57 ..... 132
Raphael Katzen
Look at Synthetic Rubber Raw Materials ..... 138
John T. Cox, Jr. & W. Whitney Weinrich
Here's the Outlook for Syndets ..... 139
Foster Dee Snell
These Petrochemicals Use Ammonia ..... 145
Lewis F. Hatch
Look Carefully at Acrolein ..... 151
Peter W. Sherwood
Growing Fast—Butadiene Material of the Future ..... 157
John C. Hillyer & P. S. Stallings
Look Again at Synthetic Rubber Industry ..... 164
J. D. D'Ianni
More Ammonia with Least Investment ..... 169
W. B. Dunwoody & J. R. Phillips
New Avenue for Capital—Oxidation of LPG? ..... 172
Ronald E. Meyer
Check List for Superfractionator Design ..... 179
S. T. Kiguchi & R. L. Ridgway
Newest Olefin Polymer—Polybutene ..... 185
Dewey Mark & Allen R. Orr
Don't Forget Markets in Plant Design ..... 187
F. Drake Parker & H. R. Jones
Which Polyethylene Process? ..... 191
R. L. Thomasson, John J. McKetta & Thomas C. Ponder
Here Are Complete OXO Reaction Data ..... 197
Irving Wender
New Separation Tool—Low Temperature ..... 201
Clyde McKinley

## OTHER TECHNICAL FEATURES

Hydrazine Cuts Water Treating Costs ..... 208
E. R. Woodward
Computer Evaluates Cooling Towers ..... 211
A. L. Fuller
Design Direct Contact Coolers Quickly ..... 215
G. H. P. Bras
Coal Beats Oil Here ..... 222
W. B. Johnson
Taking Stock ..... 230
Cecil W. Smith

## As Management Sees It

How Operations Research Aids the Refiner ..... 126
Tage A. Mortensen
Need Craft Apprentices? Try Personnel Tests ..... 266
Robert E. Chandler
Postwar Construction: From Chaos to Europe's Leading Refiner ..... 280

## DEPARTMENTS

LOOK BOX. Featuring . . .
"Oil Cannot Speak—But You Can" ..... 121
Quick Look ..... 3
Mail Box ..... 114
Quick Look at Industry ..... 117
Valuable Reading Ahead ..... 232
How To Do It ..... 234
Who's Building ..... 241
What's Happening ..... 287
Meeting Calendar ..... 305
Men In Industry ..... 306
Reviewing New Books ..... 331
Suppliers Notes ..... 334
Classified Advertising ..... 356
New Equipment ..... 362
Manufacturers Literature ..... 362
Index to Advertisers ..... 360
Readers Service Card ..... 362

# A Quick Look

## at This Issue

These handy digests permit checking ☑ those articles you want to read first.

### Petrochemical Developments

☐ **What's Ahead for Petrochemicals in '57 . . .** The petrochemical industry has entered the long predicted period of stabilization and moderate growth. Look for the large volume basic intermediates, used as raw materials, to show the greatest future growth. The outlook for '57 is very bright indeed. Study these predictions carefully to see how your company should fare. Turn to **Page 132.**

☐ **Look at Synthetic Rubber Raw Materials . . .** The present supply and the expected growth pattern of the two principal monomers—butadiene and styrene—are discussed. The future of the synthetic rubber consumption ratio—synthetic: natural—looks very favorable for continued expansion in this industry. This data can affect your plans. Turn to **Page 138.**

☐ **Here's the Outlook for Syndets . . .** Here is the latest picture of the synthetic detergent industry. These petroleum-derived materials are a big business. Just how big is explained by the current production and future trends in this rapidly expanding industry. See how your company can fit into this picture of petroleum-based anionic, nonionic and cationic detergents, turn to **Page 139.**

☐ **These Petrochemicals Use Ammonia . . .** While the primary end-use for ammonia is agriculture, the expanding consumption in the manufacture of petrochemicals is an immediate reality. Outlined here are a few of the many organic chemicals that consume ammonia. Study these outlets for your seasonal surpluses. Turn to **Page 145.**

☐ **Look Carefully at Acrolein . . .** Here is a comparison of the pro's and con's of the two methods for manufacturing this petrochemical. The future of this aldehyde, as a chemical intermediate, looks very bright. Study the advantages of each process and check your future plans for including this petrochemical. Turn to **Page 151.**

Please Turn Page →

## A Quick Look at This Issue . . .

☐ **Growing Fast—Butadiene Material of the Future. . . .** With production no longer tied to rubber end uses, this versatile raw material is causing widespread study. This article discusses some of the petrochemicals now being manufactured. Butadiene could very well be the raw material for YOUR future. Turn to **Page 157.**

☐ **Look Again at Synthetic Rubber . . .** Synthetic rubbers are bounding ahead. Here's a quick review of the five most important types. Manufacturing, end-uses and marketing are discussed. The petrochemical industry supplies all of the major raw materials. Get your share of this business. Turn to **Page 164.**

☐ **More Ammonia with Least Investment . . .** The purification of ammonia synthesis gas to remove non-condensibles will increase plant production. Accomplishing this purification at low pressure keeps down compression costs. Learn how to cut production costs and still keep investment low by turning to **Page 169.**

☐ **New Avenue for Capital—Oxidation of LPG? . . .** Production still high and profits slowly sinking? Transportation costs on finished products taking a bigger bite of profits? If these are your problems, then study this article for new avenues of expansion. The economics of this new oxygenated petrochemical process are clearly explained. Turn to **Page 172.**

☐ **Check List for Superfractionator Design . . .** Many variables enter into superfractionator design. Here are eight design factors that can influence the nine items that affect column cost. Proper control and performance require good instrumentation. Check the ten items that must be considered. Add this check list to your work book now. Turn to **Page 179.**

☐ **Newest Olefin Polymer—Polybutene . . .** Here are operating data and historical background on this interesting olefin polymer. One of the world's largest producers tells all concerning this Fridel-Crafts polymerization. Many applications of this viscous polymer are discussed. Turn to **Page 185.**

☐ **Don't Forget Markets in Plant Design . . .** The market demand for a particular product can determine the form in which it should be marketed. Design all plants with the "Market Concept" in mind and they will be flexible, adaptable and convertible to the changing markets. Study this system of applying your engineering knowledge and skills along with economic and market data to plant design problems. Turn to **Page 187.**

☐ **Which Polyethylene Process? . . .** Here is a comparison of the three low and one high pressure polyethylene processes that are commercially available. Advantages and disadvantages (known at the present time) for each process are discussed. This article will bring you up-to-date on the newest and fastest growing olefin polymer. Turn to **Page 191.**

☐ **Here are Complete OXO Reaction Data . . .** This new type of catalysis for the petroleum industry enables aldehydes to be made from olefins. The charge stocks, thermodynamics, catalysts, products and the kinetics of the reaction are explained. Learn more about this newest of the commercial petrochemical processes, turn to **Page 197.**

☐ **New Separation Tool—Low Temperature . . .** Look closely at low temperature if you have a difficult separation problem. The common features of all low temperature processes are pointed out. Applying these principles can make low temperature operations as straight forward as present standard processes. For a quick summary, turn to **Page 201.**

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☐ **Hydrazine Cuts Water Treating Costs . . .** The use of this oxygen scavenger effects a saving in material cost, improves heat transfer rates, and contributes the desired alkilinity. For details on how to use hydrazine, turn to **Page 208.**

☐ **Computer Evaluates Cooling Towers . . .** The basic equation of Merkel may be solved by a digital computer to evaluate and design countercurrent cooling towers. To learn of the speed and accuracy of this proposed method, turn to **Page 211.**

☐ **Design Direct Contact Coolers Quickly . . .** Are you passing up this useful processing tool because of the design problem? This simplified method streamlines a once tedious trial and error method of contact cooler design. Within engineering accuracy ranges it eliminates the troublesome mass transfer coefficient from the design equation. Clip this for your design files, turn to **Page 215.**

☐ **Coal Beats Oil Here . . .** SASOL, South African Coal Oil and Gas Corp., Ltd., is the world's largest synthetic fuel plant. Chemicals and motor gasoline are produced via Fischer Tropsch reaction from coal. The complete story with background and operating history is told by the prime contractor. Turn to **Page 222.**

☐ **How Operations Research Aids the Refiner . . .** Operations research has been widely publicized as an important new management tool. It has been presented as a magic formula providing near-fabulous improvements in refinery business and industrial operations. Just what is it? How does it work? What can it do? For the answers to these questions, plus several examples of operations research applications in the refining industry, turn to **Page 126.**

☐ **From Chaos to Europe's Leading Refiner . . .** Here is the last in Petroleum Refiner's postwar construction series reflecting the phenomenal growth of the refining industry since World War II. As a fitting close to PR's comprehensive study of refining's growth, we present the dramatic story of Royal Dutch/Shell's recovery from the destruction of war to become Europe's leading refiner. For a revealing insight into the brilliant operations of this world-wide company, turn to **Page 280.**

# PETROLEUM REFINER

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SUBSCRIPTIONS

R. M. de Sombre, Circulation Manager, P. O. Box 2608, Houston 1, Texas, U.S.A. Single copies 50 cents (except special issues) for U. S. and Canada; $1 for all other countries. Subscription rates—both foreign and domestic $2 a year. Subscriptions restricted to those engaged in refining, natural gasoline or petrochemical industries or service and supply company personnel connected thereto. PETROLEUM REFINER, published on the 12th of each month, entered as second class matter June 16, 1923, at the post office at Houston, Texas, under act of March 3, 1879.


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Specialized Oil Publications of
THE GULF PUBLISHING COMPANY
Box 2608, Houston (1), Texas

PETROLEUM REFINER and The REFINERY CATALOG for the refining natural gasoline-petrochemical industry

WORLD OIL (formerly The Oil Weekly) and The COMPOSITE CATALOG for the drilling-producing industry

PIPE LINE INDUSTRY and The PIPE LINE COMPOSITE CATALOG (first edition to be issued in July, 1957) for the oil and gas pipe line industry.

**Petroleum Refiner is indexed by Industrial Arts Index, Chemical Abstracts and by Engineering Index, Inc. Microfilm copies available through University Microfilms, An Arbor, Michigan.**


## 'Stoopendous' Is the Word

One with less regard for spelling than emphasis might term it "stoopendous." And inasmuch as emphasis is exactly what we're seeking here, we'll go along and climb out on the same limb with this statement: The polyethylene article by two of PR's staff members plus R. L. Thomasson (starts on Page 191) is MUST reading for everyone interested in petrochemicals.

Here a deep curiosity propelled the authors into the task of developing the details and consolidating into a single article data how the various polyethylene processes differ, the advantages and disadvantages of each, how the polymer compare physically, what unit operations are involved in each process, etc. It's all gathered together here for the first time, and has been carefully checked by authorities in the field. If it doesn't prove to be a ten-strike, then we miss our guess.

## The Giant, Maintenance

WITHIN THE last few years, modern cost analysis techniques have revealed that maintenance requires more dollar expenditures than any other refinery operation. For the year of 1957, PETROLEUM REFINER's Market Research Department estimates that the world's refining-processing industry will spend in excess of $1.5 billion for maintenance of their plant facilities. This amounts to $4.5 million dollars *per day*, which includes materials, equipment, labor, and direct overhead.

Since nearly half of all refinery, petrochemical and natural gasoline personnel are employed for maintenance operations, this vital plant function is of concern to every refinery man.

New equipment, techniques and organizational setups are constantly being devised to hold this dollar consuming giant in check. The January issue, right down this alley, will bring to maintenance men in the industry's plants, literally hundreds of ideas that will provide a means to reduce maintenance costs.

So be sure to be on the lookout for the January issue of PETROLEUM REFINER.

## To Speed You Through—

PR's STAFF during the past six weeks has devoted considerable attention to our monthly news review called "What's Happening in the Industry," Page 287 in this issue. The idea was to make it easier to read and yet give the reader what he needs in the way of news to keep him abreast of refining industry activities. Certain decisions were made and the changes are incorporated in the current presentation. We hope these changes help to speed you, the busy oil man, through this interesting section. It's hardly sufficient for you, no matter how busy you are, to stop when you have finished reading the technical section. Take the word of the heading on Page 232, that in this issue, and always, there's "Valuable Reading Ahead."

Jacketing forms around pipe easily. A two man crew can apply jacketing without special installation equipment. Aluminum strapping and seals make application simple and quick, reducing labor costs. Factory-attached moisture barrier is recommended where the presence of moisture could harm aluminum from the under side. The resin type adhesive used exclusively by Childers to bond moisture barrier to under side of jacketing withstands temperatures up to 300°F.

# 1,286 Plants in 48 States and 14 Foreign Countries

## Insure Insulation Efficiency with Childers Jacketing

**Leading engineers** world-wide specify Childers Jacketing for protecting costly insulation on lines, towers, vessels and tanks. These efficiency minded engineers prefer Childers Jacketing because of these exclusive features:

1. LAP-SEAL (patents pending) insures a more positive weather-seal.
2. Heavy weight jacketing designed for lines subject to abuse.
3. Deep Corrugated Jacketing with factory-attached moisture barrier for towers, vessels and tanks.
4. New resin adhesive that makes a stronger bond between the jacketing and the vapor barrier.

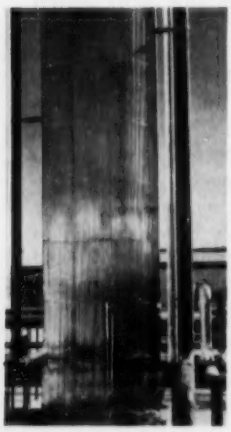
**Childers Aluminum Jacketing** provides strong, durable protection with three way savings:

1. Lower first cost than any other permanent jacketing.
2. Lower application cost because it's so easy to cut-to-size and attach.
3. Eliminates maintenance because it is made of durable aluminum for maximum corrosion resistance and requires no painting.

**Economy minded** engineers know that plant efficiency is improved when costly insulation is protected with Childers Aluminum Jacketing. And too, the gleaming beauty of Childers Jacketing makes plants brighter, neater — reduces "housekeeping" costs.

### Send for Free Sample and Prices

You can help increase the efficiency of your insulated lines, towers, vessels and tanks by using Childers Jacketing. Write today for free sample and engineering data. **Childers Manufacturing Co., Dept. PR-36, Houston 8, Texas.**

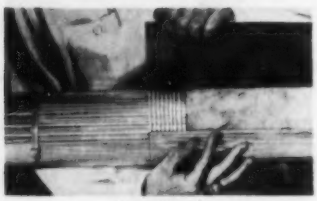


### New Deep Corrugated Jacketing For Towers, Vessels and Tanks

Only Childers offers deep corrugated aluminum jacketing with factory-attached moisture barrier. Available in 1¼" and 2½" corrugations. Childers Deep Corrugated Jacketing is used to provide permanent protection for insulated towers, vessels and tanks.

### Heavy Weight Jacketing

Only Childers offers .019" Jacketing in labor saving 4' wide rolls. This exclusive product is recommended to protect insulated lines along walkways and in other areas where they are subject to abuse; also recommended for protection of all insulated towers, vessels and tanks.



### Lap-Seal

Childers exclusive LAP-SEAL is a series of eight ribs rolled into the underlapping edge of the jacketing.

**Lap-Seal has 2 important advantages:**

1. Where desired, a positive weather seal is easily made with Lap-Seal and a mastic.
2. Lap-Seal provides an automatic measure of the 2" circumferential lap. It saves labor, insures proper lap and prevents waste.

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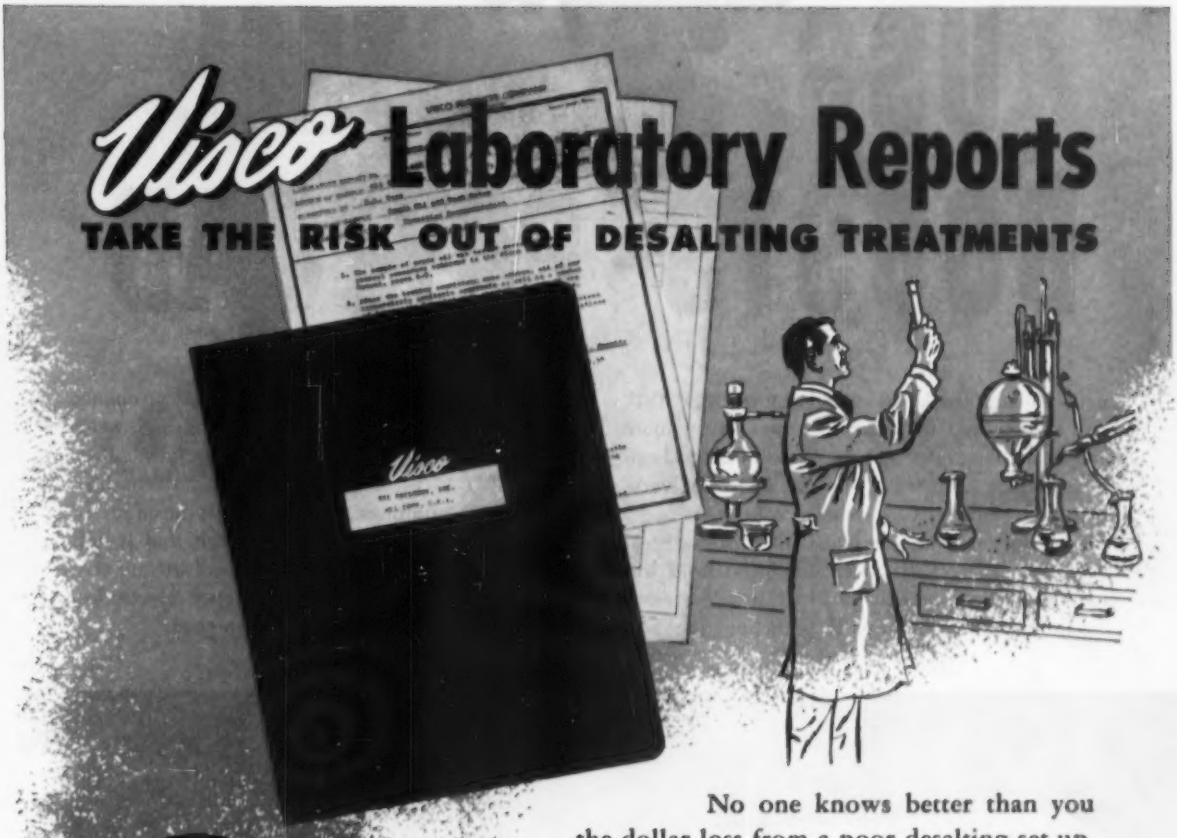


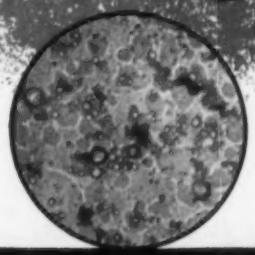

Photomicrograph—
Emulsified refinery crude

No one knows better than you the dollar loss from a poor desalting set-up.

And you know, too, there's no such thing as a blanket cure-all. But a Visco Laboratory Report *does* point the way to the results you want—from every type of crude—at no added cost to you.

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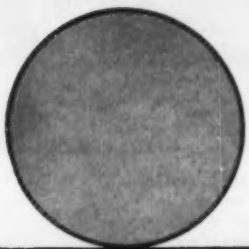

Photomicrograph—Emulsified refinery crude after Visco desalting

If you would like our desalting recommendation for your crude, send Visco a five-gallon can of the crude and one gallon of the water used in your refinery desalting. Or better yet, check with your Visco representative, and he will arrange for these services.

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It was for jobs like this that United States Steel developed USS "T-1" Steel. Jobs that need tremendous strength to withstand high tensile stresses . . . tremendous toughness to withstand jars and jolts, and to perform in any weather with no chance of brittle failure. Jobs that demand good weldability to cut the cost and difficulty of fabrication.

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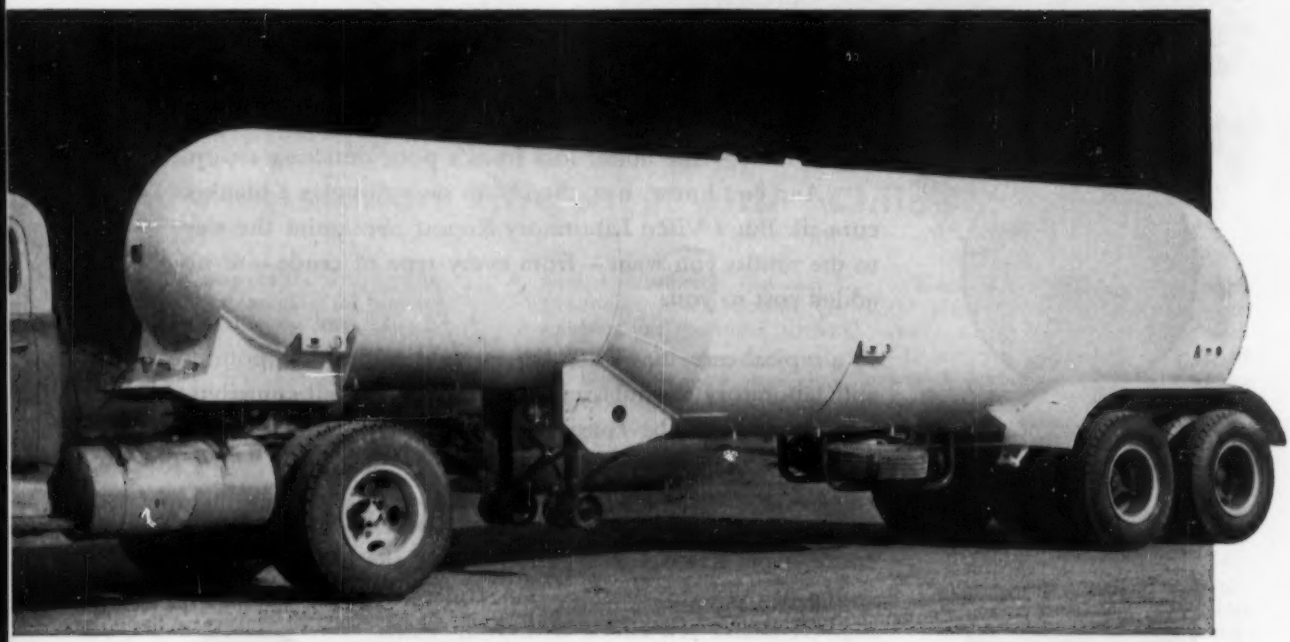

**FREE LITERATURE** Case 1204, a special ruling of the ASME Boiler and Pressure Vessel Committee, gives full particulars about the use of "T-1" in vessels, which can be applied to mobile tank units. Write for your free copy. We'll also send you full technical information on the use of "T-1" in other applications where it enables you to reduce weight or cost, or to increase strength or durability in rugged service. Write or wire, United States Steel, Room 5549, Pittsburgh 30, Pa.

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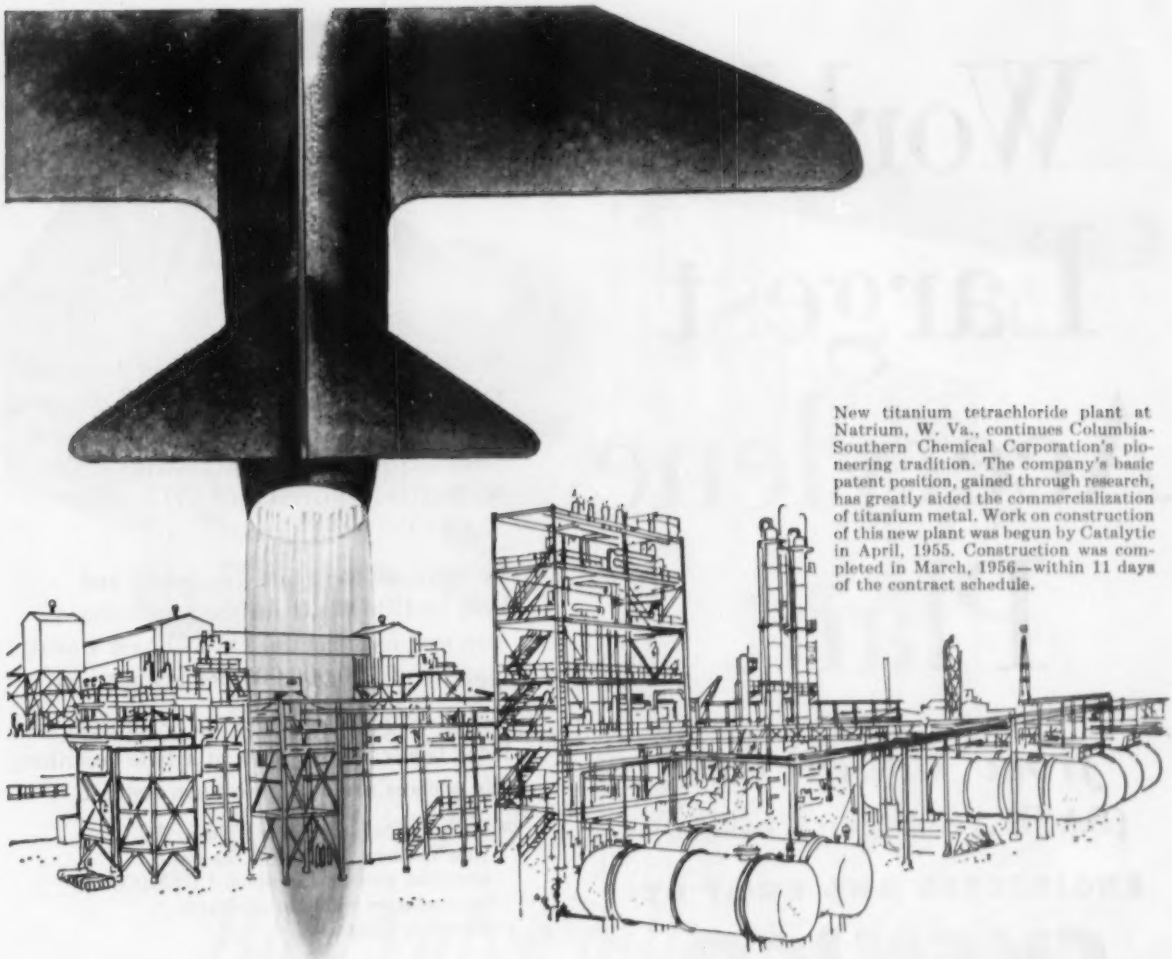
**USS "T-1" CONSTRUCTIONAL ALLOY STEEL**

USS

UNITED STATES STEEL



New titanium tetrachloride plant at Natrium, W. Va., continues Columbia-Southern Chemical Corporation's pioneering tradition. The company's basic patent position, gained through research, has greatly aided the commercialization of titanium metal. Work on construction of this new plant was begun by Catalytic in April, 1955. Construction was completed in March, 1956—within 11 days of the contract schedule.

**$TiCl_4$**
(Titanium tetrachloride)

A new multi-million dollar plant at Natrium, W. Va., is the answer of *Columbia-Southern Chemical Corporation* to the task of producing $TiCl_4$—titanium tetrachloride—which in turn is used in production of titanium.

Titanium is metallurgy's answer to the need for metal resistant to high temperatures—as in supersonic aircraft.

Titanium tetrachloride—the product of this new plant engineered and constructed by Catalytic—has opened up important markets in diversified other fields as well as in production of titanium sponge. Its many uses include the manufacture of catalysts for plastics, the making of titanium esters, and service as a reducing agent for dyes.

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## Construction Company

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for the metallurgical, chemical, petrochemical and oil refining industries: Project Analysis; Process Development; Process Design; Economic Studies; Engineering; Procurement; Construction; Plant Operation



For more data on advertised products, use Readers' Service Cards, last page.

# World's Largest Acetylene Plant

## *from Natural Gas*
## (BASF Acetylene Process)

**ENGINEERED AND BUILT BY**

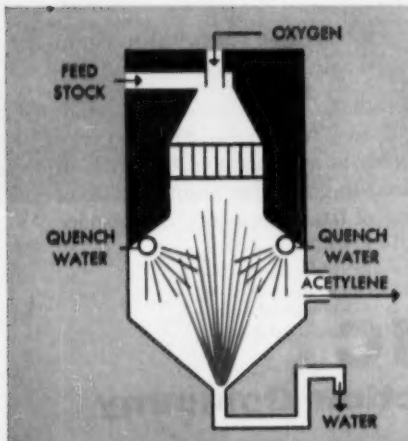
# CHEMICO

The BASF* **Acetylene Plant** of American Cyanamid Company at Avondale, Louisiana, engineered and built by CHEMICO, is now being increased in capacity, making it the WORLD'S LARGEST ACETYLENE PLANT OF ITS TYPE.

By 1957, all the plants engineered and built by CHEMICO for the production of acetylene from natural gas will have a total capacity of 150,000,000 pounds per year.

Important features of the BASF process are listed below, and reprints of article describing this process are available upon request.

* Badische Anilin & Soda Fabrik, AG, West Germany, holder of the basic acetylene process for which CHEMICO has exclusive rights in all North American Countries.




### Features of the BASF Acetylene Process

**Produces commercially pure acetylene, meeting specifications for the manufacture of acetylene derivative products such as Acrylonitrile, Vinyl Chloride, Methylstyrene, etc.**

**Permits the use of a variety of feed stocks such as Methane, Ethane, Propane and other petroleum gases.**

**Produces off-gas suitable for Ammonia and Methanol synthesis.**

**Permits integrated production of Acetylene and Ammonia to meet changing market demand.**

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The new Rockwood Bronze Ball Valve for use with steam offers you many unusual benefits.

**It Handles up to 125 Pounds of Steam** per square inch and 350°F, with ease.

**It's Leakproof** — even after continued use Rockwood Steam Ball Valves stay dry.

**It Opens and Closes Quickly** — only a quarter turn is needed to open or close Rockwood Ball Valves.

**It Has Longer Wear-Resistance** — chrome-plated bronze ball withstands abrasion, scratching and pitting.

Rockwood's new Ball Valve for use with steam comes in pipe sizes from ¾" up to 2". Send coupon for full information and data. Distributors in all principal industrial areas.

**ROCKWOOD BALL VALVES**

**FULL, ROUND FLOW**

ROCKWOOD

**ROCKWOOD SPRINKLER COMPANY**
**1285 Harlow Street**
**Worcester 5, Mass.**

Send me illustrated folder on Rockwood's new Ball Valve for use with steam.

Name.....

Title.....

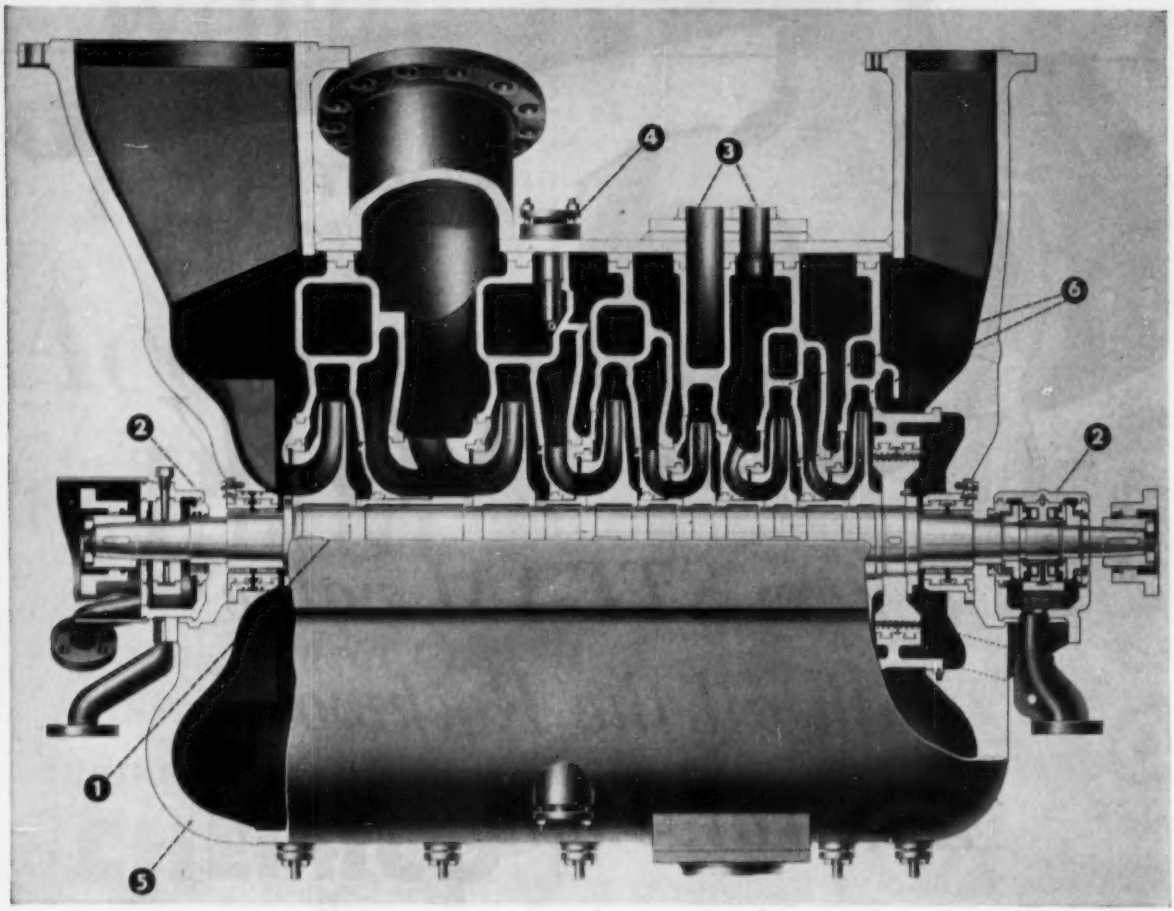
Company.....

City.....Zone..State.....



For more data on advertised products, use Readers' Service Cards, last page.

# Worthington announces new centrifugal compressor with 6 stand-out features




Worthington's GUR multi-stage compressor is the result of intensive surveys conducted among the nation's leading industrial engineering, maintenance and operating personnel. Their recommendations, plus Worthington's famous high quality standards of manufacture and design, have combined to produce this advanced compressor!

The GUR—characterized by maximum accessibility plus ease of installation and maintenance—offers you:

**1. Casings and diffusers horizontally split** at centerline with no bolting of the diffusers to the casing. This design guarantees maintaining pre-established internal clearances during reassembly. It also simplifies your installation problem and permits much greater ease of maintenance and inspection.

**2. External Bearings.** Mounted completely external to the casing and open to atmospheric pressure. Bearing maintenance and inspection is simplified. Bearing oil is prevented from contaminating the gas being compressed.

**3. Accommodations for large bleed-in bleed-out flows** permits handling of different levels of refrigeration or stepwise compression of process loads and knockouts with one compressor casing.

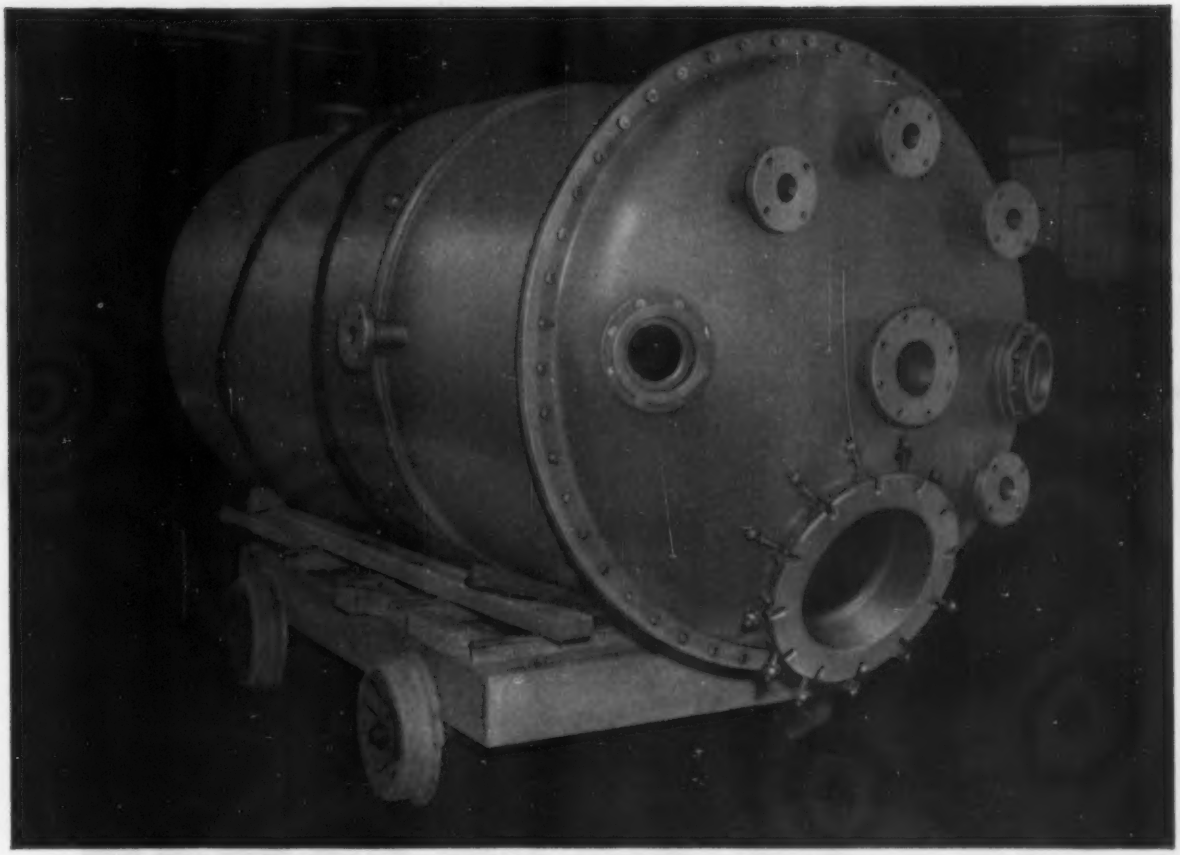
**4. Liquid injection cooling** reduces heat of compression. It eliminates need to dismantle compressor to clean water passages and maintenance associated with exchanger bundles.

**5. Castweld fabricated design** insures known sound components from basic materials to finished product. Customer benefits because we can control tolerance between calculated designed compressor weights and actual finished weights. Castings are small and inspected before assembly. There's less scrap risk—shipping dates are realistic.

**6. Horizontally split enclosed diffusers** allow continuous gas guidance through compression range. Compressor casing is not used as part of diffuser. Should corrosion or erosion occur, only a particular defaced diffuser need be replaced—not entire casing.

The Worthington Multi-Stage compressor is designed for use with air, ammonia and most hydro-carbon gases. Five casing sizes give a capacity range from 570 to 82,000 C.F.M. per casing with discharge pressure to 950 psig. For details, contact your Worthington District Office...or write Section A-6121, Worthington Corporation, Harrison, N.J.

**WORTHINGTON**



**Steel Steam-jacketed Still with bonded lead lining.** This unit, placed on side for transport through plant, is five feet I D by eleven feet deep. All surfaces exposed to corrosion carry a ¼" lead lining bonded to the steel by National Lead's unique, improved process.

# National Lead weds lead to steel

## *. . . boosts life of lead-lined vessels*

Lead-steel bonds in lead-lined equipment have never been as satisfactory as they are today . . . thanks to the improved process by which National Lead *weds* lead to steel.

Mechanical abuse – impact, crushing, twisting – does not destroy the bond. "Torture tests," designed to pry the lead from the steel, do not separate the metals at the interface . . . the union is stronger than the tensile strength of lead.

**Virtually indestructible**

With the improved bonding method you get the kind of lining performance in massive vessels that you get from National Lead "Tubond" pipe and "United" valves. Pressure, vacuum, vibration and heat (short of lead's melting point) don't disturb the lead-steel bond. Blistering, buckling and cracking are virtually eliminated even under severe and rapid cyclic temperature changes.

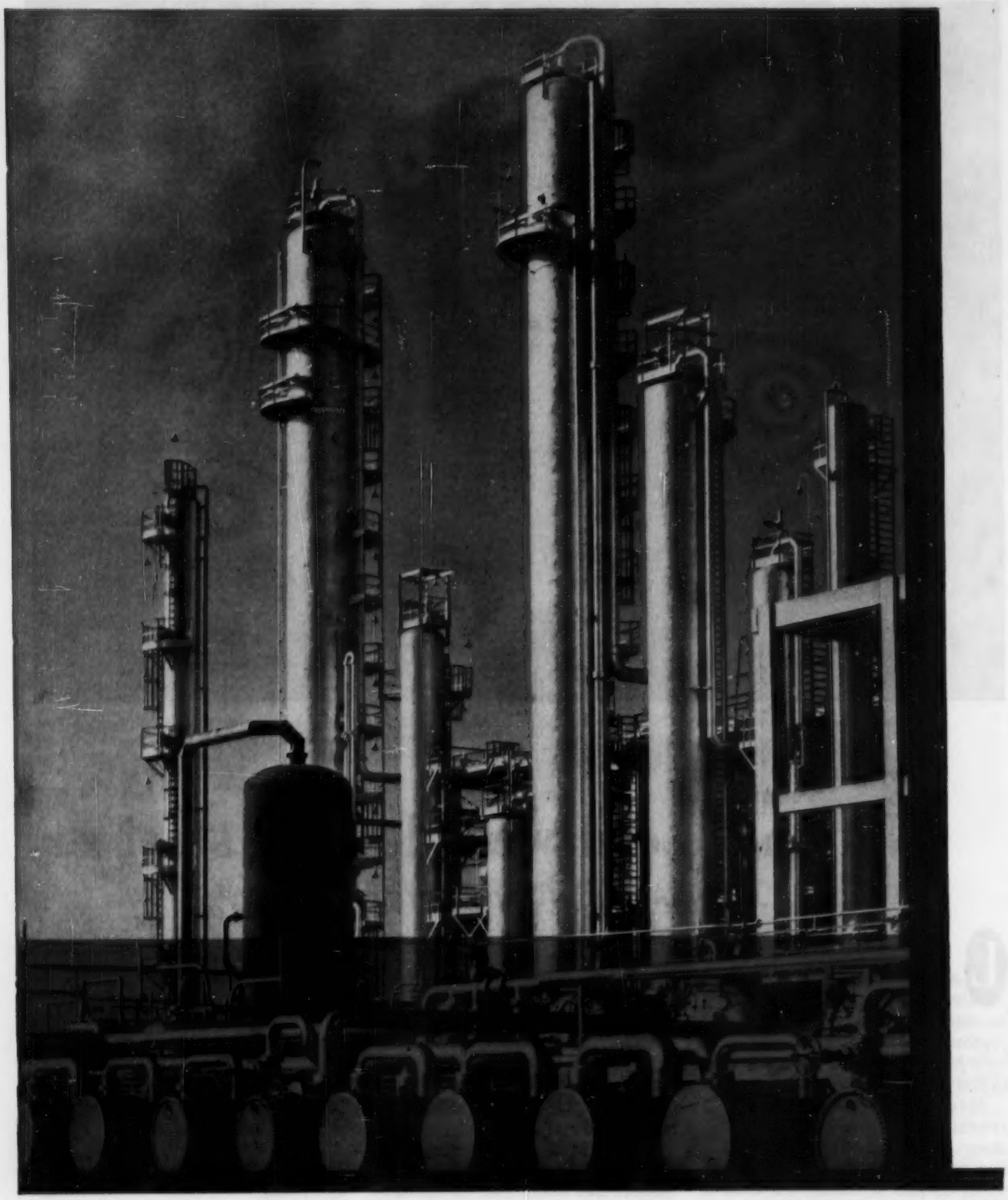
If your processing employs corrosives, National Lead fabricated vessels can bring you major savings in maintenance costs and cut losses due to production stoppages.

National Lead makes lead-lined equipment of all types and sizes, from small-bore "Tubond" pipe to tank cars and beyond. Write for quotations on any acid-handling equipment you have in prospect, furnishing, if possible, sketches or prints, and information on type of corrosive, flow factors, temperatures, pressures and other operating data. Address National Lead Company, Lead-Lined Dept., 111 Broadway, New York 6, N. Y.

## National Lead Process Vessels

## *. . . lined to last*

For more data on advertised products, use Readers' Service Cards, last page.



**FIRST FOR LASTING QUALITY—FROM MINE TO MARKET!**

*For dependable "on-stream" performance . . .*
*retube your exchangers with*

# PHELPS DODGE HEAT EXCHANGER TUBES!

Wide selection of copper-base alloys for every type of application—including bi-metal combinations.

Complete warehouse stocks maintained at Houston, Texas; Tulsa, Okla.; Los Angeles, Cal.; Chicago, Ill.; and Bayway, N. J.

Expert assistance in solving your tube corrosion problems.

*Specify Phelps Dodge . . . One of the largest suppliers of tubes to manufacturers of heat exchangers!*

**PHELPS DODGE COPPER PRODUCTS CORPORATION**

**SALES OFFICES:** Atlanta, Birmingham, Ala., Boston, Buffalo, Charlotte, Chicago, Cincinnati, Cleveland, Dallas, Detroit, Fort Wayne, Greensboro, N. C., Houston, Jacksonville, Kansas City, Mo., Los Angeles, Milwaukee, Minneapolis, New Orleans, New York, Philadelphia, Pittsburgh, Portland, Ore., Richmond, Rochester, N. Y., San Francisco, St. Louis, Seattle, Washington, D. C.



**For more data on advertised products, use Readers' Service Cards, last page.**

# How to IMPROVE Catalytic Cracker PERFORMANCE

**YORKMESH DEMISTERS** in Vacuum Towers effectively remove entrained asphalt to provide clean gas oil. The improved catalytic cracker charging stock with decreased carbon and metal contaminants results in —

**HIGHER THROUGHPUT** rates due to reduced load on the regenerator;

**HIGHER YIELDS** of liquid products due to high catalyst activity maintained for longer periods.

York engineers will review your operating conditions and recommend the best Demister from the several styles available, which include the new "Triple H" high-efficiency, homogeneous, herringbone Yorkmesh Demister.

**WRITE** for Bulletin 18 and Case Studies 1001, 1002 and 1004 from our technical library for specific information on vacuum tower installations.

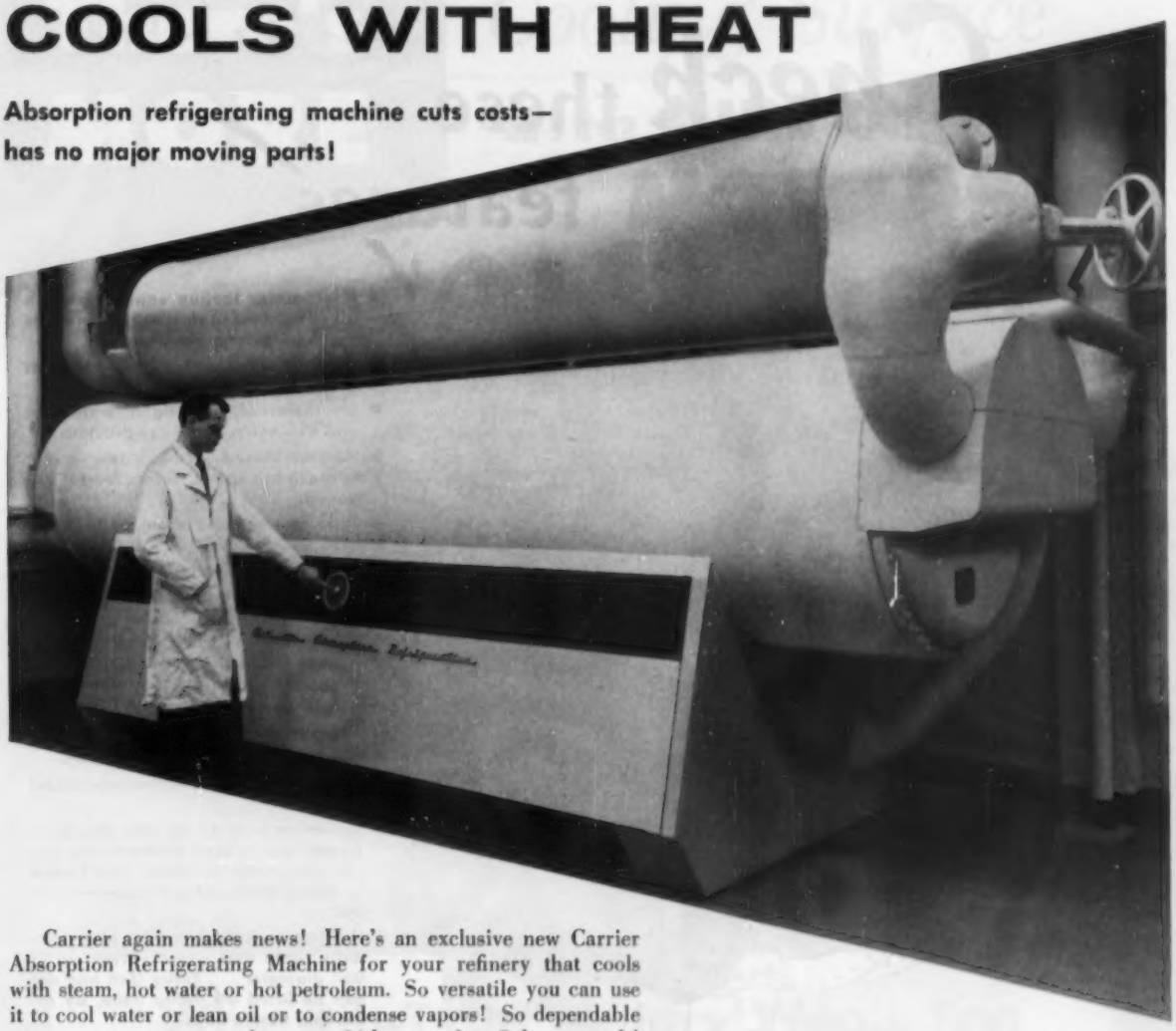
YORK

**OTTO H. YORK COMPANY, INC.**
6 Central Avenue, West Orange, N. J.

*Specialists in* **FLUIDS SEPARATION / ENGINEERS and MANUFACTURERS**

# Exclusive New Carrier Machine
# COOLS WITH HEAT

**Absorption refrigerating machine cuts costs—has no major moving parts!**



Carrier again makes news! Here's an exclusive new Carrier Absorption Refrigerating Machine for your refinery that cools with steam, hot water or hot petroleum. So versatile you can use it to cool water or lean oil or to condense vapors! So dependable you can count on top performance 24 hours a day, 7 days a week!

**Low-cost cooling?** You can get it with Carrier absorption refrigeration! Waste steam or hot liquids from other processes in your refinery are the energy source. Electricity is used only for small pumps and controls—there are no major moving parts!

**Automatic operation?** You can get it with Carrier absorption refrigeration! You push a single button to start the machine, push that same button again to stop it. No highly trained operator is needed. Electronic controls do all the "thinking."

**A machine that follows cooling needs to *zero capacity*?** You can get it with Carrier absorption refrigeration! It's the only refrigerating equipment that will operate in a completely automatic cycle from 100% full load down to zero capacity without expensive controls, and do it with a perfectly smooth operating curve.

And you get still other advantages from Carrier absorption refrigeration. Light weight. Compact design. Simple maintenance. A wide range of capacities—100 to 700 tons of cooling.

Get the full story. Call your nearest Carrier office for your copy of a new 36-page booklet on Carrier Absorption Refrigerating Machines. Or write Carrier Corporation, Syracuse, New York.

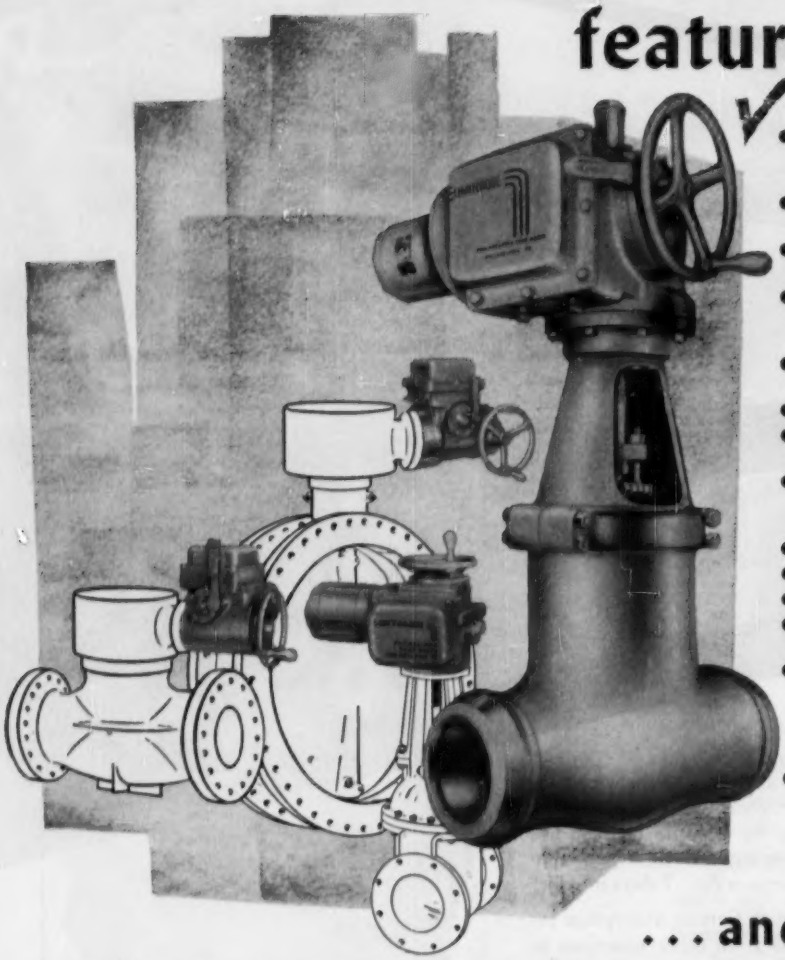
**Carrier**

**centrifugal compressors**
**refrigerating equipment**



For more data on advertised products, use Readers' Service Cards, last page.

# Check these features



- Micrometer torque seating switch gives tight valve closure, and protects valve parts from damage.
- Self contained unit—no gears, stem nut or bearings to buy.
- Weatherproof, dust-tight, watertight and explosion-proof construction.
- Hammerblow device . . allows motor to reach full speed, before load is engaged.
- Non-rotating handwheel built into the unit.
- Automatic declutching.
- Motor is disengaged during handwheel operation.
- Can always be declutched for handwheel operation regardless of weather or electrical conditions.
- High torque motors.
- Simple valve yoke.
- May be mounted in any position.
- Three to four times faster handwheel operation.
- Actuation may be by any available power source such as electricity, air, oil, gas, water or steam. LimiTorque is readily adapted for microwave control.
- LimiTorque is designed for plug, butterfly, gate and globe valves up to 96" diameter . . . Entire Unit and nut can be lifted off valve yoke, by removing flange bolts.

## . . . and you'll understand why more *LIMITORQUE* valve controls are in use than all others combined

Send for new catalog L-550, and please use your Business Letterhead when requesting.

**LimiTorque®**

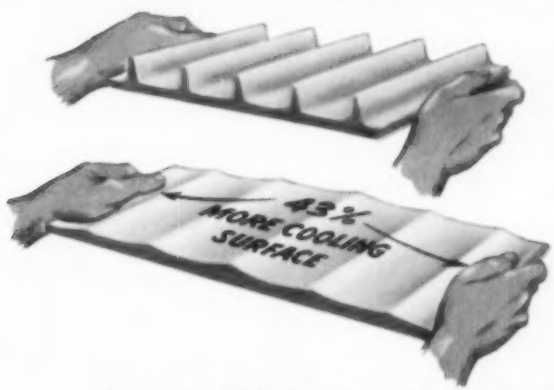
PHILADELPHIA GEAR WORKS, INC.
ERIE AVE. & G STREET. PHILADELPHIA 34. PENNA.
Offices in all Principal Cities

INDUSTRIAL GEARS & SPEED REDUCERS • LIMITORQUE VALVE CONTROLS • FLUID MIXERS • FLEXIBLE COUPLINGS

Limitorque Corporation • Philadelphia

# There's MORE *Cooling Surface* with Allis-Chalmers MOTORS

## Why Rib-Type Motors Won't Fry




**STRETCH OUT RIB DESIGN** of Allis-Chalmers motors and see the greater cooling area provided — as much as 43% on many models. Insulation won't fry under normal conditions with deep-rib construction because every rib adds to the heat-dissipating surfaces. The result—moderate overloads can be taken in stride with little fear of burnouts.

As a new machinery component or as replacement, specify Allis-Chalmers. To find out more, contact your nearby A-C district office, distributor, or write Allis-Chalmers, General Products Division, Milwaukee 1, Wisconsin.

# ALLIS-CHALMERS

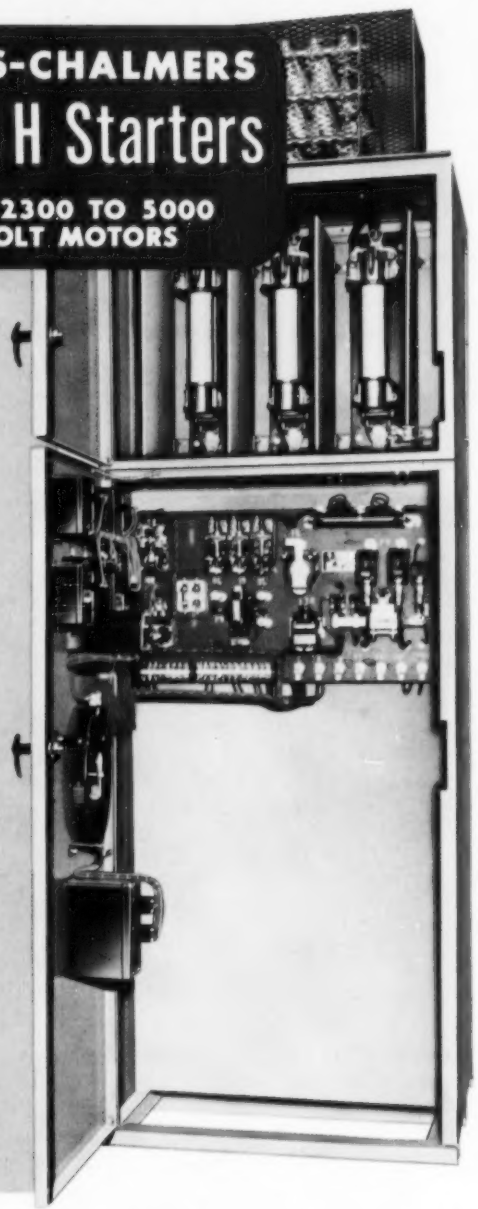
A-4882

# CHOICE of CONTACTORS

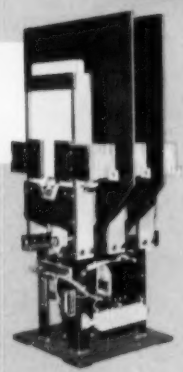
## to meet your specific needs

***Allis-Chalmers Type H Starters may be equipped with either air-break or oil-immersed contactors — installed in the same sized space.***

**ALLIS-CHALMERS**
**Type H Starters**
**FOR 2300 TO 5000 VOLT MOTORS**

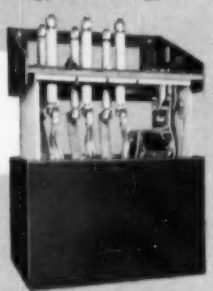


## AIR



Designed for top performance on the rough-tough jobs. Advantage of contacts operating in air include long contact life, reduced fire hazard, easy maintenance. Double-break contacts, vertical action and dual blowouts provide long, dependable operation. Design simplicity makes contactor particularly adaptable for applications requiring frequent starting, inching, reversing, or dynamic braking.

## OIL



Meets operating demands of semi-hazardous locations. Contactor operates under oil to prevent sparks from igniting atmosphere and to protect mechanism from corrosion. Contactor is time-proved clapper type. Self-cleaning, rolling-wiping action extends contact life. Self-aligning E-type magnet provides perfect armature seating . . . quiet, maintenance-free operation.

## YOU GET MORE...

Allis-Chalmers offers help on specific control application problems. Call your Allis-Chalmers representative. His recommendations are backed by Allis-Chalmers engineering departments . . . by the experience gained in solving thousands of control problems . . . by complete research and testing facilities.

For complete information on the Type H starter, write for Bulletin 14B6410B — Allis-Chalmers, General Products Div., Milwaukee 1, Wis.

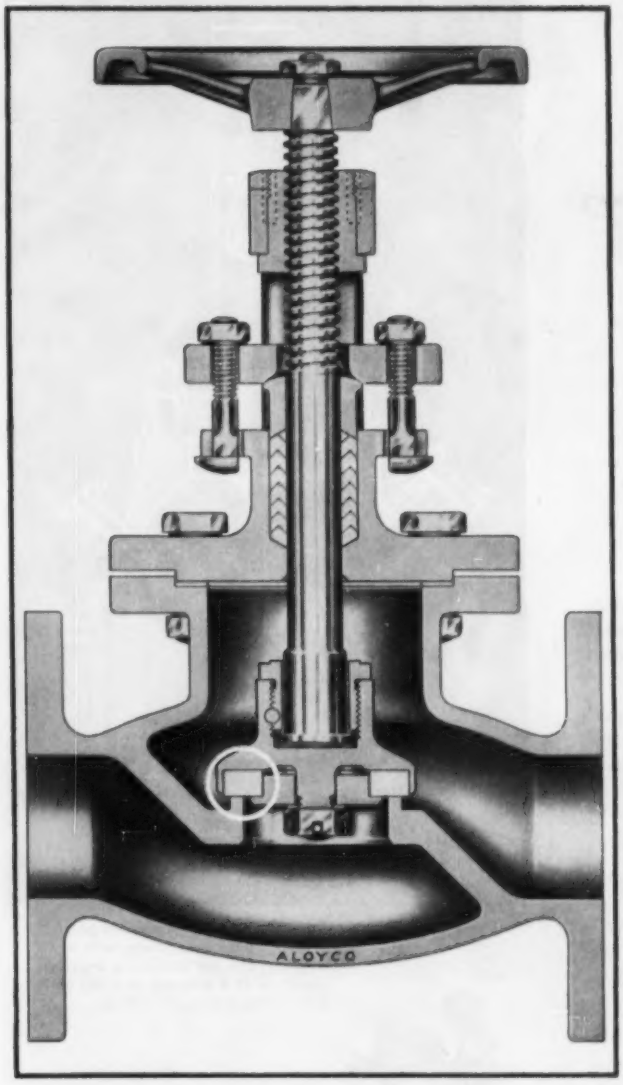
A-C ALLIS-CHALMERS

# ALLIS-CHALMERS

A-4976

# Teflon* forms gas-tight seal in corrosion resistant Aloyco valves

*Registered DuPont trademark.

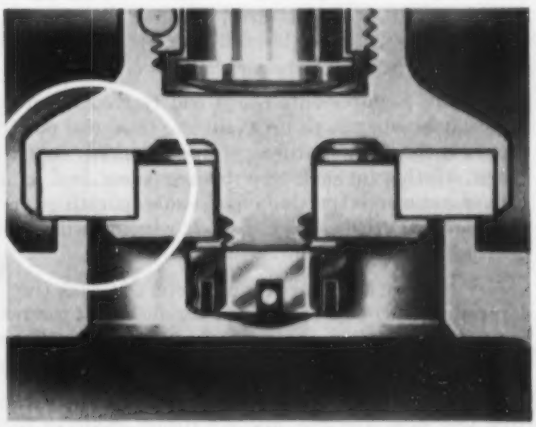



Hard-to-hold volatile or elusive fluids—even if highly corrosive—can't leak past the Teflon discs or packing in this Aloyco valve.

The reason? Teflon's ability to form a gas-tight seal under compression—*even when the seating surface or adjoining metal is slightly corroded.* That's why Teflon-equipped valves outlast and outperform valves with metal-to-metal seating surfaces in handling volatile corrosive fluids.

Add to that the fact that Teflon has high impact strength under hydraulic shock loads, and is inert to almost all chemicals up to 500° F., and you'll see why Aloyco pioneered the use of this unique material for discs, seats and packing in corrosion-resistant valves.

Aloyco valves with renewable Teflon discs, seats, and packing come with screwed or flanged ends in a variety of styles: globe, Y, angle, swing-check, needle, plug-gate—as well as sampling valves. You'll find them all described in our new bulletin No. 11. Mail coupon below for your copy. 4.4



**ALOYCO GLOBE VALVE** holds Teflon disc securely against possible overload.

*Longer Lasting*
**ALOYCO**
**VALVES**
1ST IN CORROSIVE SERVICE

*Subsidiary of Walworth Company*

**Alloy Steel Products Company, Inc.**
**1303 West Elizabeth Avenue**
**Linden, New Jersey**

**Gentlemen:**

Please send me a free copy of your new Bulletin No. 11 on Aloyco valves with renewable Teflon discs or seats.

Name_____

Firm_____

Address_____

City_____ Zone_____ State_____

# BLAW-KNOX Autoclaves furnished in a size and type

## ...*for every pressure and temperature application*

### with all auxiliary equipment, when desired, for a complete high pressure plant

Blaw-Knox has designed, constructed and equipped autoclaves in all practical sizes, ranging from one quart capacity upward to the largest commercial sizes with total capacities of several thousand gallons.

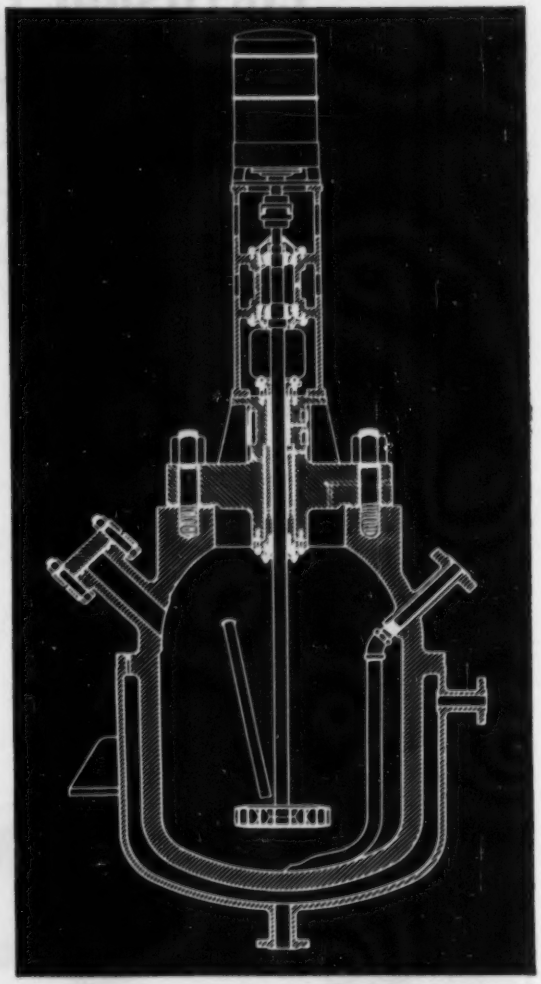
Pressure requirements range widely from vacuum and atmospheric operations up to several thousand pounds per square inch. Temperatures, where required, cover a full range starting at sub-zero temperatures and going as high as commercial needs dictate, some operating at 800° F. and higher, with heating methods ranging with the temperatures to be reached.

Any suitable material of construction is used, the choice depending on the materials and conditions of the reaction under consideration. Many different agitator types are available to meet every conceivable mixing requirement.

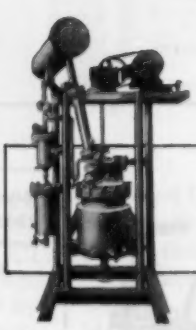
In other words, Blaw-Knox has the engineering knowledge and skill and the manufacturing facilities to build any size, any type autoclave or kettle for use for hydrogenation, ammonolysis, polymerization, or organic synthesis, for batch products of chemicals, drugs and medicines or resins, and for general chemical processing.

No matter what your reaction problem is, whether with low pressure—low temperature, or highest pressure—high temperature conditions, why not discuss it with us. We will gladly give you our recommendations.

Ask for Catalog 2413-R.



Drawing of a Blaw-Knox 120-gallon Steam Jacketed Autoclave, with turbine agitator, for processing organic chemicals at a pressure of 2000 psi and a temperature of 300° F.

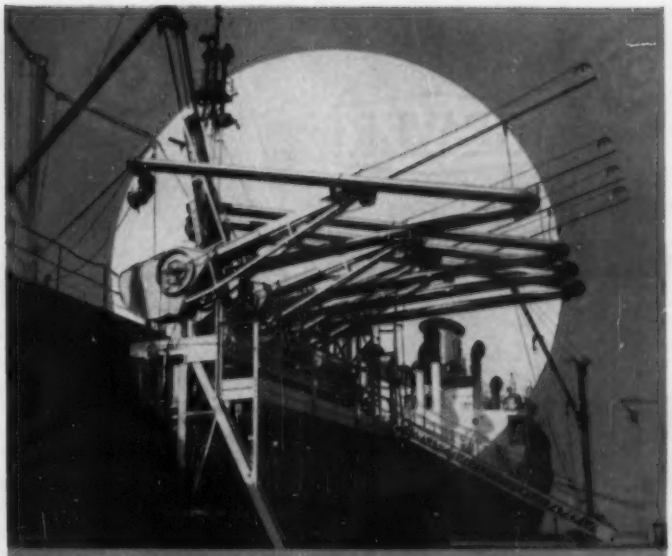


Photograph of a Blaw-Knox 15-gallon Electro-Vapor Processing Kettle, widely used in the resin and chemical industries.

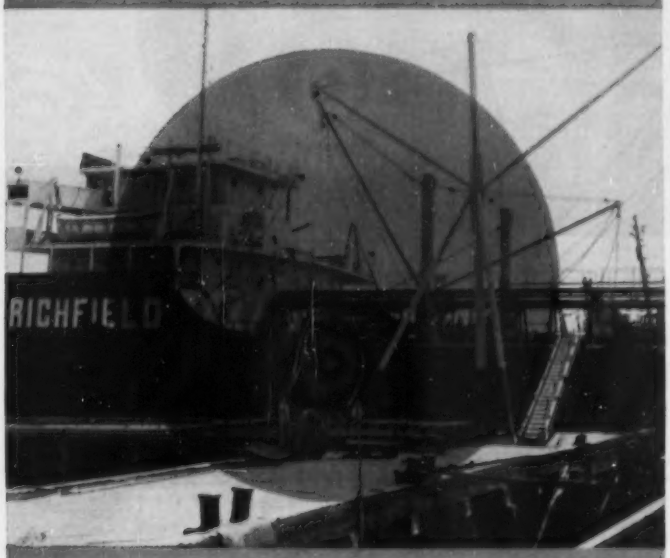
50th Anniversary BLAW-KNOX 1906 1956

**BLAW-KNOX COMPANY**

*Buflovak Equipment Division, 1601 Fillmore Avenue, Buffalo 11, N. Y.*



**NOW**—One man operating simple controls swings Chiksan Loading Arms into hook-up position in one minute. Note spotless condition of the dock.




**BEFORE**—Unwieldy dock hose was difficult to make up, was hazardous, cluttered the dock and was subject to spillage.

# RICHFIELD TERMINAL GOES MODERN WITH CHIKSAN MARINE LOADING ARMS

Safety. Economy. Speed. These three major factors were carefully weighed by Richfield when they evaluated the new Chiksan Marine Loading Arm. On each point the new Loading Arm measured up and more.

Take safety. The majority of marine loading mishaps are back injuries resulting from handling heavy rubber hose. The new hydraulically operated loading arm eliminates this costly hazard. Hose bursts, while less common, are extremely dangerous, terrifically expensive... one burst cleanup could easily cost more than an entire 5-arm unit. The new Chiksan Loading Arm has a burst ratio of 8 to 1 compared with rubber hose 4 to 1 ratio.

From a speed standpoint, it takes 3 men just 7 minutes to make up the Chiksan Loading Arm compared with 7 men taking 24 minutes with rubber hose. Loading operations can be speeded up, materially reducing turnaround time.

And from the all important economy viewpoint, the new Loading Arm means substantial savings in lost man-hours due to injuries, insurance and compensation premiums, and expensive rubber hose replacement costs. Savings that within a decade will actually amour.t to the purchase price of the Loading Arm.

## CONSULT CHIKSAN NOW

If your planning includes a new dock, Chiksan will provide specific detail so that installation requirements can be included in the original plans. If it's an existing dock, Chiksan will tailor loading facilities to meet your requirements.

**CHIKSAN**

A SUBSIDIARY OF FOOD MACHINERY AND CHEMICAL CORPORATION

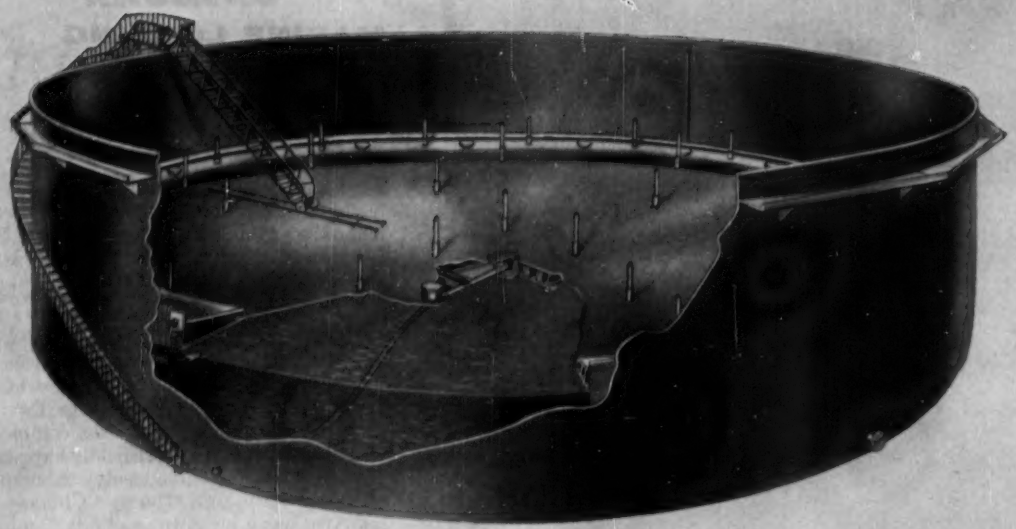
fmc

**CHIKSAN COMPANY**—BREA, CALIFORNIA • CHICAGO 5, ILLINOIS • NEWARK 2, NEW JERSEY

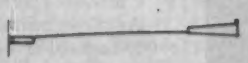
Well Equipment Mfg. Corp. (Division), Houston 1, Texas • Subsidiaries: Chiksan Export Company • Chiksan of Canada, Ltd.

GRAVER

# WE'VE CLEARED THE DECK...

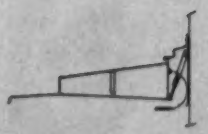


**STABLE . . . because, ship-like, the center of buoyancy is below the center of gravity.**



**CORROSION-RESISTANT . . . because the liquid in storage is in full contact with the deck.**

**SELF-DRAINING . . . rainfall flows to the Graver sump at the center low point of the roof.**



**VAPOR-STOP SEAL . . . Graver's patented single seal . . . proved effective against vapor loss.**

## . . . FOR A NEW, LOW-COST FLOATING ROOF TANK WITH UNDER-DECK CENTER WEIGHT

Here is another outstanding Graver first in single-deck floating roof tanks. We've cleared the deck for easy snow removal and positive drainage by putting the center weight *below* the deck. This effects additional economies in construction without sacrificing the long-established advantages of Graver's patented single-deck floating roof principle and characteristic Graver quality. This new Graver floating roof tank (both pontoon and pan type) has been thoroughly proved by installations across the nation. May we give you complete details?

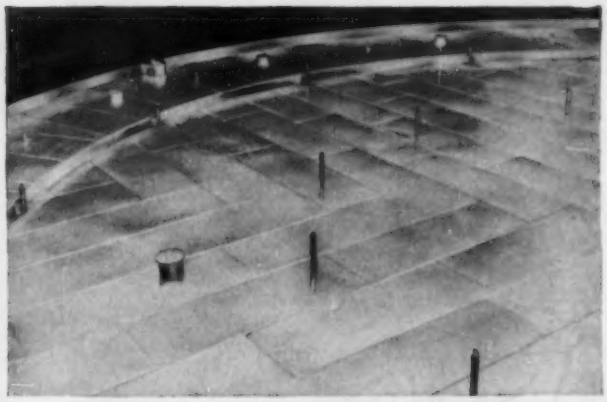
GRAVER

GRAVER TANK & MFG. CO., INC.

EAST CHICAGO, INDIANA • NEW YORK • PHILADELPHIA • EDGE MOOR, DELAWARE
PITTSBURGH • DETROIT • CHICAGO • TULSA • SANDS SPRINGS, OKLAHOMA
HOUSTON • LOS ANGELES • FONTANA, CALIFORNIA • SAN FRANCISCO

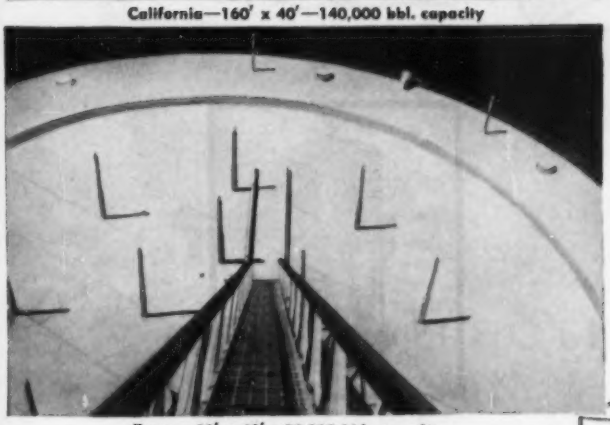


For more data on advertised products, use Readers' Service Cards, last page.



New Jersey—140′ x 40′—110,000 bbl. capacity

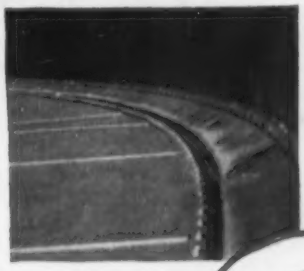
California—160′ x 40′—140,000 bbl. capacity



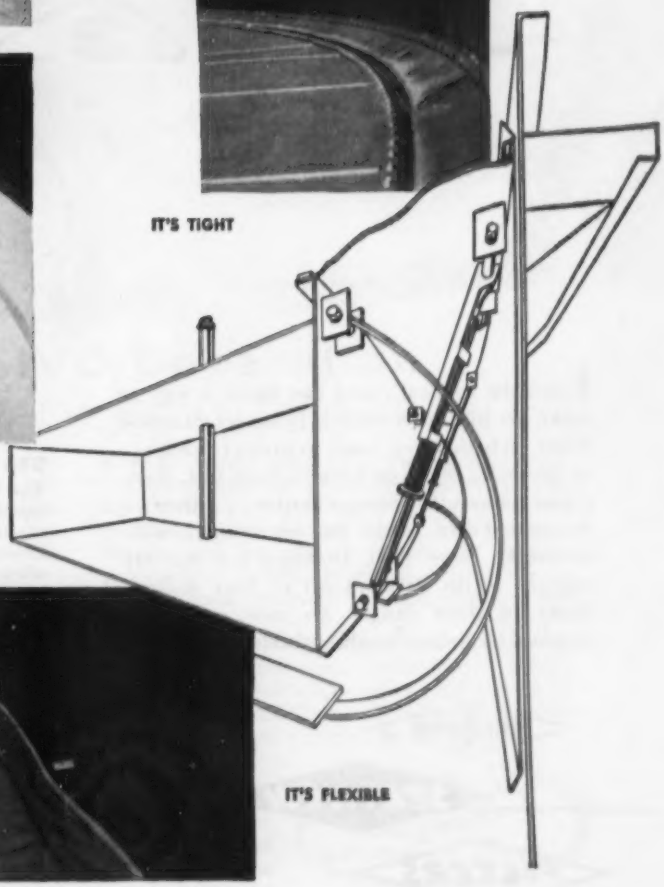
Texas—90′ x 48′—55,000 bbl. capacity

## PROVED WHERE ECONOMY COUNTS...

The demands for more production and greater storage capacity with the least investment has attracted a number of well-known companies to the new low-cost Graver under-deck center-weighted floating roof tank. The typical installations at the left show the obvious advantages of Graver's new clear-deck single roof in all climates.



IT'S TIGHT



GRAVER®

IT'S FLEXIBLE

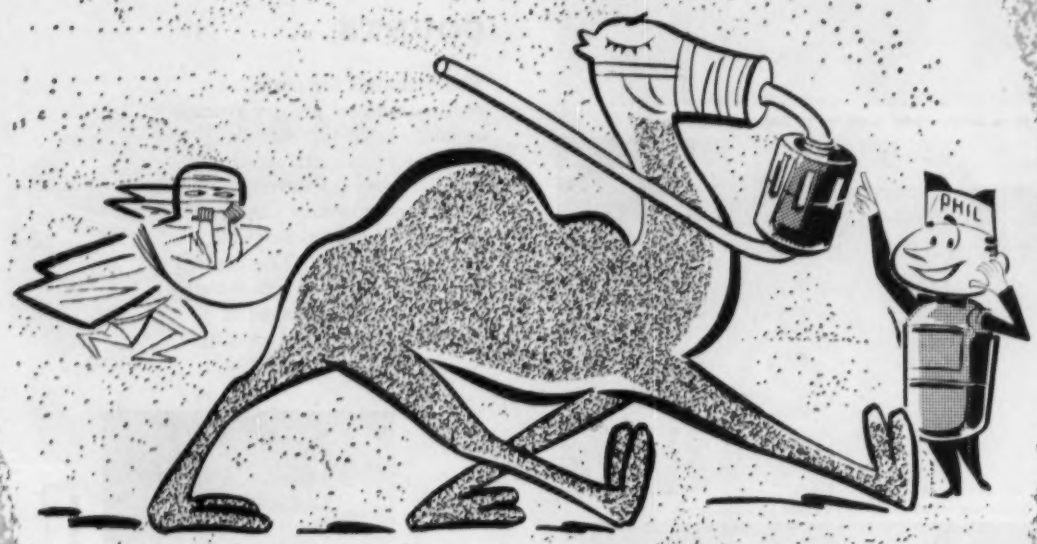
### SINGLE VAPOR-STOP SEAL

Graver's patented Vapor-Stop single seal is an inherent feature. This effective seal rides "tight" over weld seams on new construction and rivets on re-roofed tanks.



For more data on advertised products, use Readers' Service Cards, last page.

# KEEP IT CLEAN...by Phil Tration



Even the comical camel can figure a way to make his job easier with a Dollinger Staynew Filter. Whether you want to protect machines or processes, walls or workers from dirt, dust, grease, oil or other foreign matter . . . there's a Staynew Filter to do the job economically, efficiently. Since 1920, Dollinger has actively engaged in the development of filter designs. Many of these designs are now considered *standard* by industries throughout the world.

**STAYNEW MODEL ELS LIQUID FILTER**

The world-wide use of Dollinger filters on hundreds of liquids is proof of their adaptability to practically any requirement. All known filtering materials are available for any problem regardless of temperature, pressure, or efficiency desired. And, all Model ELS Liquid Filter bodies are available in steel, stainless, monel, herculoy and other non-corrosive metals. Construction can be according to ASME Code specifications.

Send for 12-page Bulletin 300. It contains illustrated data and recommended uses of Dollinger Liquid Filters. Dollinger Corporation, 47 Centre Park, Rochester 3, N.Y.

PROTECTOMOTOR

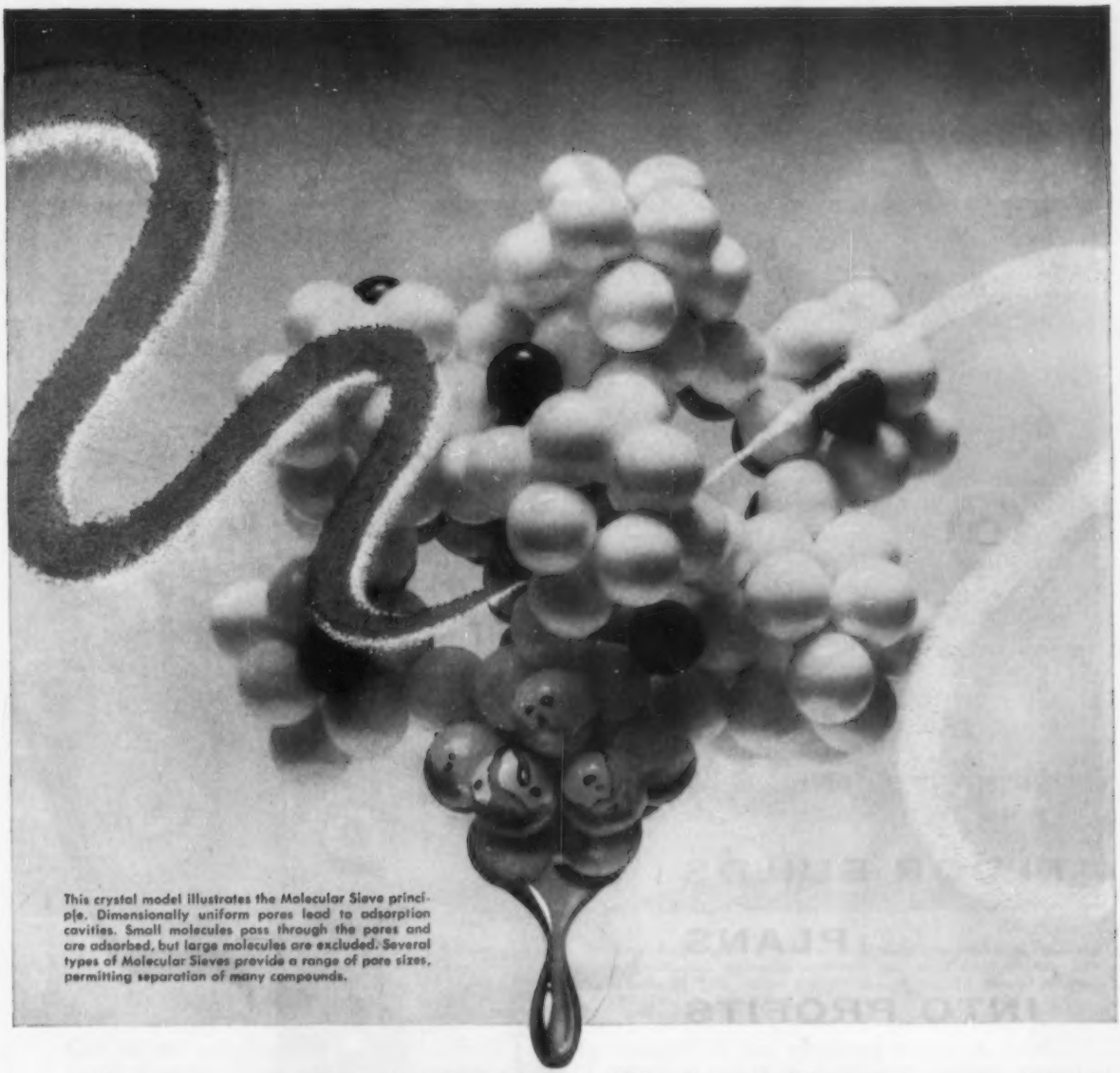
STAYNEW **DOLLINGER**

FILTERS

LIQUID FILTERS • PIPE LINE FILTERS • INTAKE FILTERS • HYDRAULIC FILTERS • ELECTROSTATIC FILTERS • MIST COLLECTORS • DRY PANEL FILTERS • SPECIAL DESIGN FILTERS • VISCOUS PANEL FILTERS • LOW PRESSURE FILTERS HIGH PRESSURE FILTERS • AUTOMATIC VENTILATION FILTERS • NATURAL GAS FILTERS • SILENCER FILTERS



For more data on advertised products, use Readers' Service Cards, last page.



This crystal model illustrates the Molecular Sieve principle. Dimensionally uniform pores lead to adsorption cavities. Small molecules pass through the pores and are adsorbed, but large molecules are excluded. Several types of Molecular Sieves provide a range of pore sizes, permitting separation of many compounds.

# Now... SELECTIVE Separation with MOLECULAR SIEVES

LINDE Molecular Sieves, a new *class* of adsorbents, offer unique performance in product purification and recovery. These crystalline zeolites provide selective separation of gas and liquid mixtures in *three* ways... difference in molecule size... or polarity... or carbon bond saturation.

Selective removal of contaminants, even in trace amounts, is possible at temperatures up to 300° F. Selective recovery of valuable stock is often accomplished without regard to relative boiling points. Co-adsorption eliminates extra processing steps by removing several impurities simultaneously. High capacity is realized through a wide range of operating conditions.

Typical uses for Molecular Sieves are the separation of n-paraffins from iso-paraffins and cyclics . . . extraction of olefins from refinery streams and top gases . . . removal of catalyst poisons from olefins . . . sweetening of natural gas and reformer hydrogen . . . purification of annealing gases.

For a descriptive booklet, "Molecular Sieves for Selective Adsorption," write Dept. PR-12, Linde Air Products Company, A Division of Union Carbide and Carbon Corporation, 30 East 42nd Street, New York 17, N. Y.

Linde TRADE MARK MOLECULAR SIEVES

The term "Linde" is a registered trade-mark of Union Carbide and Carbon Corporation



For more data on advertised products, use Readers' Service Cards, last page.

*everywhere in the petroleum industry...*

## FLUOR BUILDS PLANS INTO PROFITS

In 1956 the Mexican Petroleum Industry (Petroleos Mexicanos) dedicated its newest unit, the expanded and modernized refinery at Minatitlan, on Mexico's East Coast. Included in the project are a TCC unit with fresh-feed capacity of 10-12,000 bbl daily and total capacity of 15,000 bbl daily, two 25,000 bbl crude distillation units, a catalytic polymerization unit, and complete supporting and offsite facilities.

Petroleos Mexicanos placed complete responsibility for design of all units in the hands of The Fluor Corporation, Ltd. As an example, steam-generating facilities, an integral part of the refinery, were designed by Fluor's Power Engineering Department. In addition, all construction – from site preparation to plant completion – was supervised by Fluor representatives at the site. As a result the plant has met all expectations.

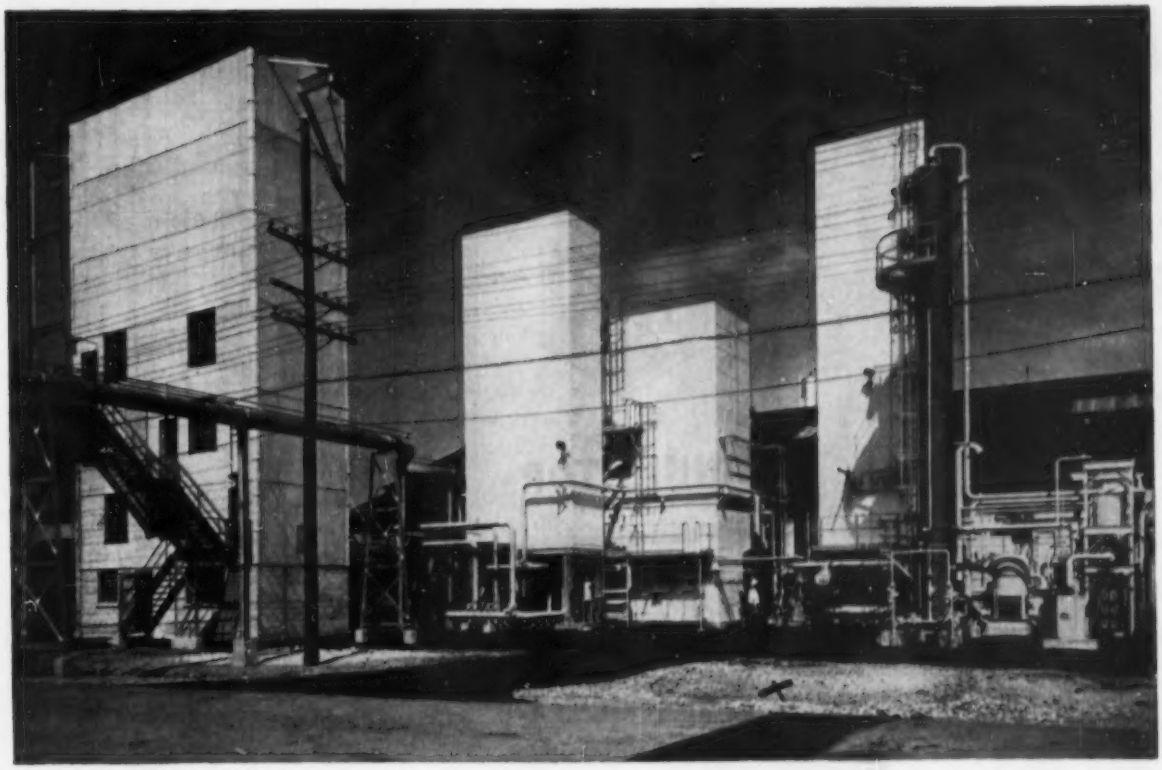
When your plans for expansion call for single units or complete refineries in any part of the world, *be sure to include Fluor.*

**FLUOR** *ENGINEERS and CONSTRUCTORS*
*for the Petroleum, Chemical & Power Industries*

*The FLUOR CORPORATION, Ltd., Los Angeles – Mid-Continent Division, Houston – Fluor of Canada, Ltd., Toronto – Fluor Maintenance, Inc., Martinez, Calif. – Singmaster & Breyer, Inc., New York City*

# NEW HYDROGEN SOURCE FOR NH3

## by low-temperature processing of coke-oven gas



Ketona Chemicals' low-temperature processing plant at Birmingham, Alabama, featuring scrubbing unit (center) producing ammonia synthesis gas and air-separation unit (right) with a daily capacity of 3.78 million cfd of nitrogen and 33 tons of oxygen.

CHEMICAL processing is the latest industry to benefit from the steady advances of low-temperature process technology, with its inherent higher efficiencies and definite economies. This technique is now being used with significant results in the field of ammonia synthesis.

Ketona Chemical, at Birmingham, Alabama, has successfully inaugurated the first ammonia plant in this country designed exclusively around coke-oven gas as a source of hydrogen. The plant was designed and built by American Air Liquide for The Fluor Corporation.

Low-temperature gas separation plants are used to recover a variety of high-purity products, including Hydrogen, Carbon Monoxide, Methane, Ethylene, Oxygen, Nitrogen, and rare atmospheric gases. During the past fifty years Air Liquide has designed and built over 1000 hydrocarbon and air-separation plants for industries throughout the world. In the United States it is a leader in this field.

Address your inquiries to: American Air Liquide, 529 Chrysler Building, New York 17, N. Y.

***In Canada:***

***Air Liquide,***
***1111 Beaver Hall Hill,***
***Montreal, Que.***

AMERICAN

**AIR LIQUIDE**

ENGINEERING & CONSTRUCTION DIVISION

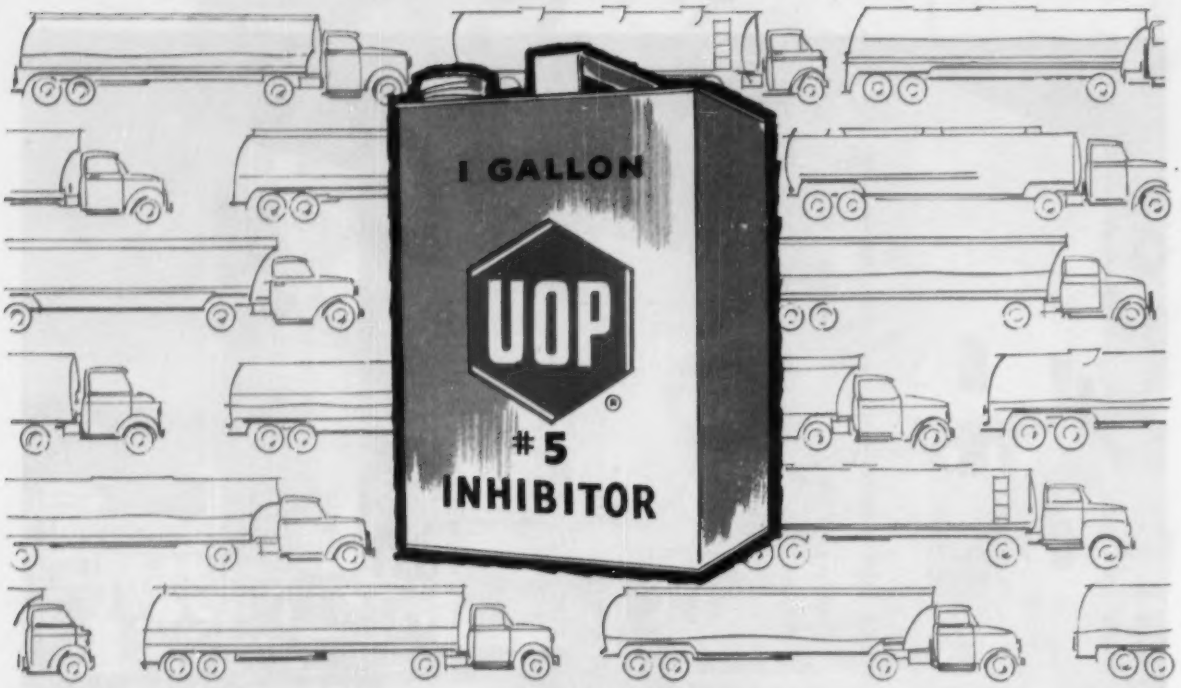
OLDEST IN EXPERIENCE — NEWEST IN DESIGN

529 CHRYSLER BUILDING, NEW YORK 17, N.Y.



For more data on advertised products, use Readers' Service Cards, last page.

# IT TAKES ONLY ONE GALLON OF UOP #5...




# TO KEEP 100,000 GALLONS OF GASOLINE GUM-FREE

UOP #5 Inhibitor is the most economical you can use. And by experience and test it is also the best—the only inhibitor that can handle the really tough stability jobs.

Actually, only 5 molecules of UOP #5 will protect as many as 1,000,000 molecules of today's tailor-made gasoline from the formation of gum, the one universally recognized cause of engine manifold deposits. It's effective, too, in preventing the decomposition of TEL in stored gasoline. Is it any wonder that UOP #5 is the standard of comparison in the industry?

Just as the methods of making better gasoline keep changing, so do the techniques of finishing gasoline for maximum gum stability and engine cleanliness. We will be glad to share our experience in this field with you in attacking a current stability problem or in reducing costs on present processing. Just write us.

PRODUCTS DEPARTMENT

UOP

**UNIVERSAL OIL PRODUCTS COMPANY**

30 ALGONQUIN ROAD, DES PLAINES, ILLINOIS, U. S. A.

# New pipe insulation has vaporproof and fireproof finish for fast application

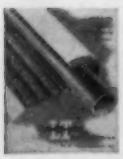
One fast operation combines application and finishing when you use Armstrong LT Cork Covering on cold lines. This entirely new kind of insulation is made of cork segments adhered to an aluminum foil and asbestos paper backing that seals out moisture vapor and resists fire. Application is amazingly fast. The paper flap is cemented quickly into place and end joints sealed with a vaporproof tape. Fittings are insulated with Armstrong Plasticork® or field fabricated covers of LT Covering.

LT Cork Covering is only one of the quality products in the complete line of Armstrong Industrial Insulations. Armstrong also offers you a contracting service, geared to install these products economically and efficiently.

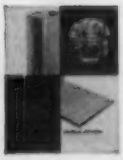
Send for free booklet on LT Cork Covering or for information on other Armstrong products that can help you solve your insulation problems.

Armstrong

INDUSTRIAL INSULATIONS



☐ Armstrong LT Cork Covering, a New Cold Line Insulation



☐ Armstrong Armabestos* Pipe Covering and Block Insulation

☐ Armstrong Armatemp* Block and Blanket Insulation

☐ Armstrong Armaglas* Insulations for Pipes, Tanks, and Vessels

Armstrong Cork Company
2012 Ream Ave.
Lancaster, Penna.

Please send me the free booklets checked. ☐
Please have an Armstrong representative call. ☐

Name .....

Position .....

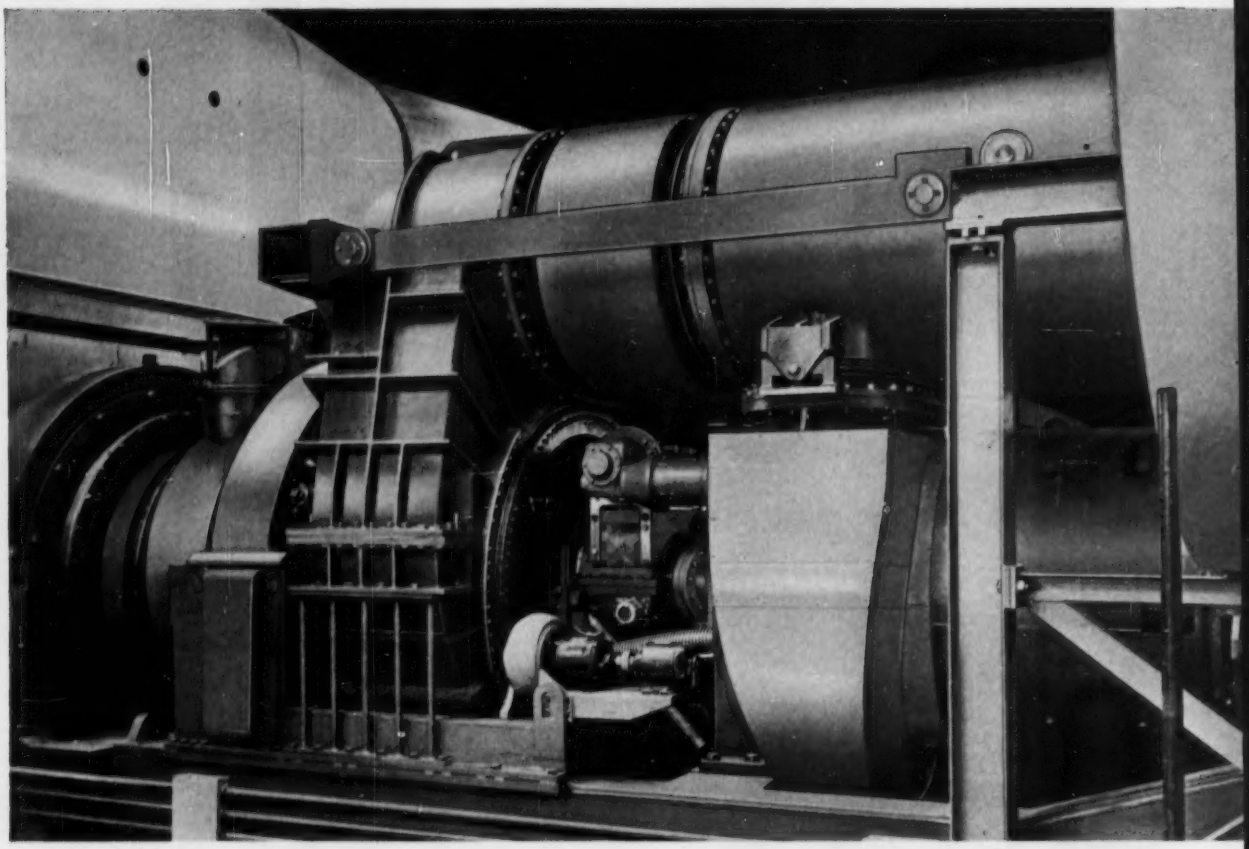
Company .....

Address .....

City ..... Zone .... State .....

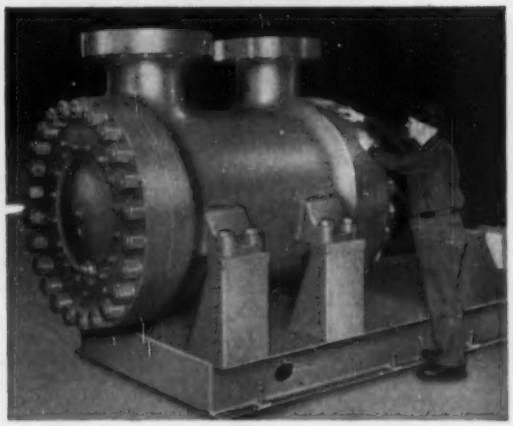
*TRADE-MARK

# GAS TURBINES



Clark 8500 BHP Gas Turbine for centrifugal compressor, generator or pump drive

Clark Barrel Type Centrifugal Compressors for extremely high pressures



CLARK®

GAS TURBINES
CENTRIFUGAL COMPRESSORS



For more data on advertised products, use Readers' Service Cards, last page.

# CENTRIFUGAL COMPRESSORS
# Only CLARK builds both!

Now you can get centrifugal compressors and modern gas turbines to drive them *exclusively* from one manufacturer . . . Clark.

In addition to saving money and headaches, you'll get proved, matched-performance "packages" specifically designed for continuous trouble-free service.

Whether you have a million or a billion cubic feet of air or gas per day to handle at pressures of up to 4500 pounds per square inch, there is a Clark centrifugal compressor and in most cases a matching Clark gas turbine to drive it.

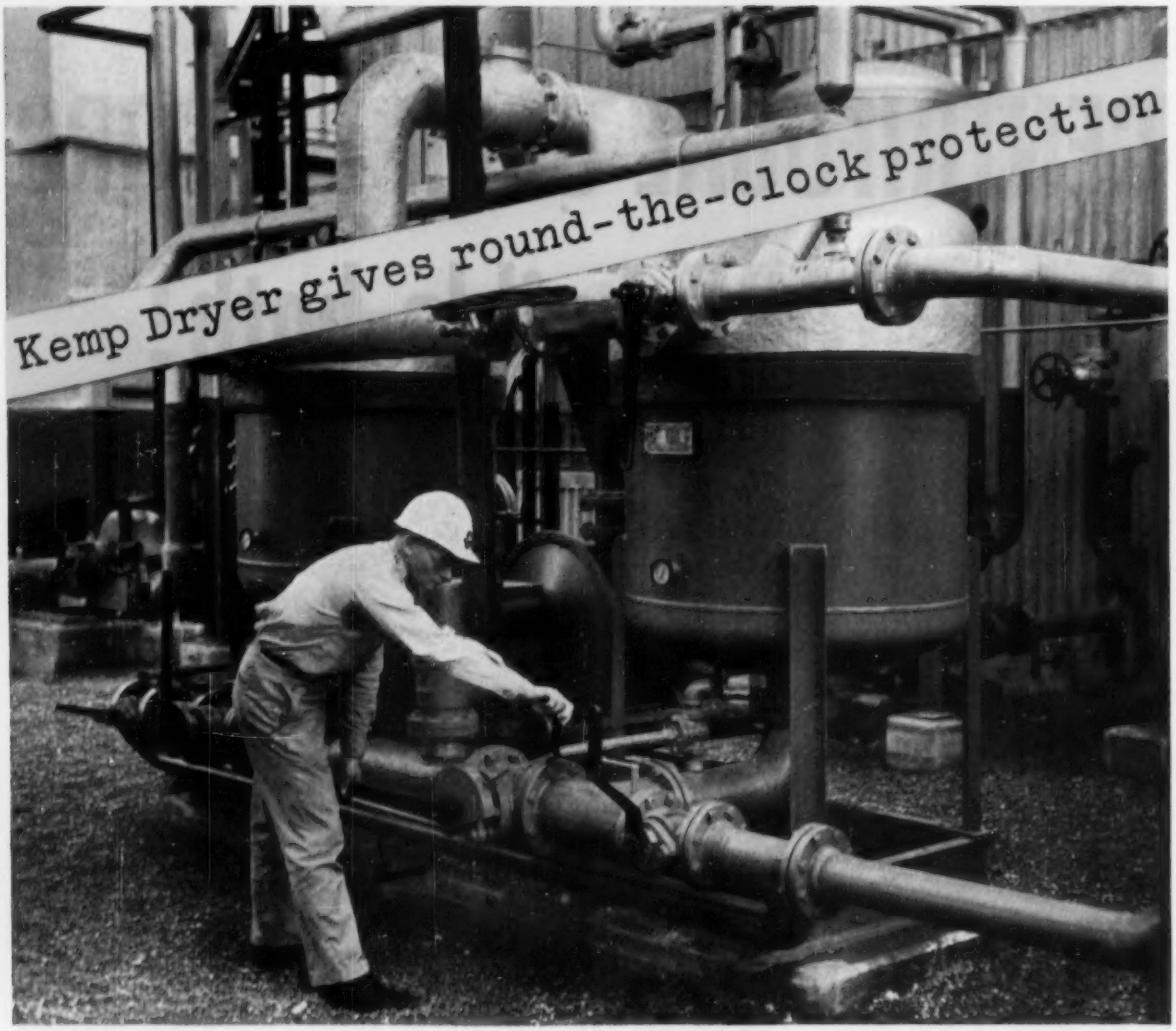
*Your nearest Clark representative will be pleased to give you all the facts.*

**CLARK BROS. CO., OLEAN, N. Y.**
*One of the Dresser Industries*
Offices in Principal Cities throughout the World

Clark Multi-Stage Centrifugal Compressors for process application

Clark Centrifugal Pipeline Booster for low ratios and high pressures

For more data on advertised products, use Readers' Service Cards, last page.




## Grace Chemical Company Reports: *Kemp Dryer safeguards instruments throughout plant 24 hours per day*

The Grace Chemical Co. manufactures Anhydrous Ammonia and Urea 24 hours a day at Woodstock, Tenn. This operation demands instrument accuracy with a minimum of maintenance and downtime. To increase instrument efficiency by preventing corrosion and costly line freezes, Grace Chemical installed a Kemp Dryer.

### Kemp Requires Little Attention

Semi-automatic, the Kemp Dryer works night and day drying compressed air for instruments and pneumatic controlled valves. According to operator Charles Lewis, the Kemp unit requires a bare minimum of attention.

### Kemp Dryers for Every Purpose

Kemp offers a variety of dryer models to meet all problems. Designed to dry air, gases or liquids to sub-zero dew points at a low cost, they are constructed of quality materials and embody the engineering knowledge gained from Kemp's many years of experience. Kemp Dryers are available with manual, semi-automatic, or fully automatic tower reactivation. In addition, Kemp will prescribe the proper desiccant for each drying job. If you have a problem involving the removal of water from air, gases, or liquids, contact Kemp engineers now. For complete facts and technical information, write for Bulletin D-27.

**KEMP OF BALTIMORE**

**DYNAMIC DRYERS**

CARBURETORS • BURNERS • FIRE CHECKS
METAL MELTING UNITS • INERT GAS GENERATORS
SINGEING EQUIPMENT

**THE C. M. KEMP MFG. CO.**
405 East Oliver Street, Baltimore 2, Maryland



For more data on advertised products, use Readers' Service Cards, last page.

# There's one right way to buy pressure tubes—it's tube life per dollar: *Ask the experts!*

*This month's report is on:* **DM STEEL**

Has unusually high creep strength for a pearlitic steel, good stability up to 1200° F., fairly good corrosion and oxidation resistance. Has 2 to 3 times the life of carbon steel where corrosion is not severe. Recommended for cracking furnace tubes, hot oil lines, superheater tubes, high temperature steam piping and forgings for accessory parts.

**ONE OF 24 TIMKEN HIGH TEMPERATURE STEELS**

| | | | |
|---|---|---|---|
| Carbon | Sicromo 2 | Sicromo 5S | 18-8 Ti |
| Carbon-Mo. | Sicromo 2½ | Sicromo 5MS | 16-13-3 |
| DM-2 | 2½% Cr.-1% Mo. | Sicromo 7 | 25-20* |
| Silmo | Sicromo 3 | Sicromo 9M | 25-12* |
| DM | 4-6% Cr.-Mo. | 18-8 Stainless | 35-15** |
| 2% Cr.-Mo. | 4-6% Cr.-Mo.-Ti. | 18-8 Cb | 16-25-6** |

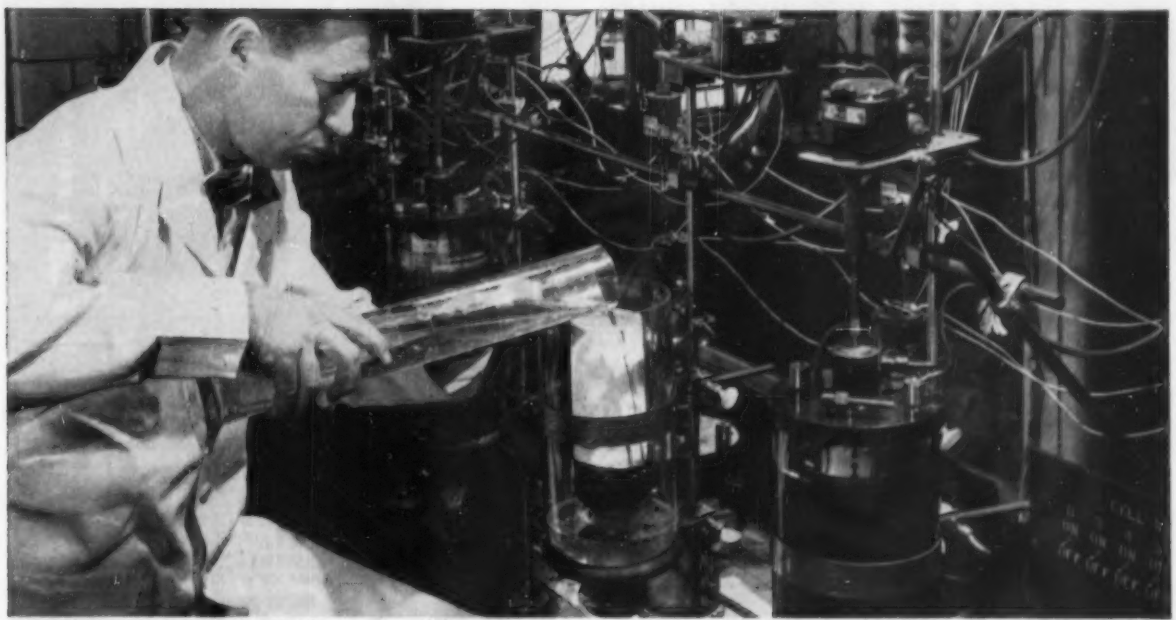
**Available as seamless tubing on an experimental basis only.*
***Not available as seamless tubing.*

YOU'RE fortunate in having the Timken Company's large choice of high temperature tube steels that will solve your heat, pressure, corrosion and oxidation problems. You're even more fortunate when you choose the *one* analysis that will give you maximum tube life per dollar—the only true index to actual tube steel cost.

To find it, *ask the experts!*

These experts are the metallurgists of The Timken Roller Bearing Company. They'll put their more than 20 years of steel research and experience—with emphasis on high temperature steels—at your disposal. Help you select from 24 different analyses the one tube steel that will give you the best life/cost ratio. Regardless of which analysis you select, you'll be assured of uniform quality. Because the Timken Company rigidly controls quality from melt shop through final inspection.

Let the Timken Company's metallurgists help solve your tube problems. *Ask the experts!* The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".



*Electrolytic equipment used in Timken Company laboratories to extract non-metallic inclusions from steels in research on steel cleanliness*

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH

**SPECIALISTS IN FINE ALLOY STEELS, GRAPHITIC TOOL STEELS AND SEAMLESS TUBING**



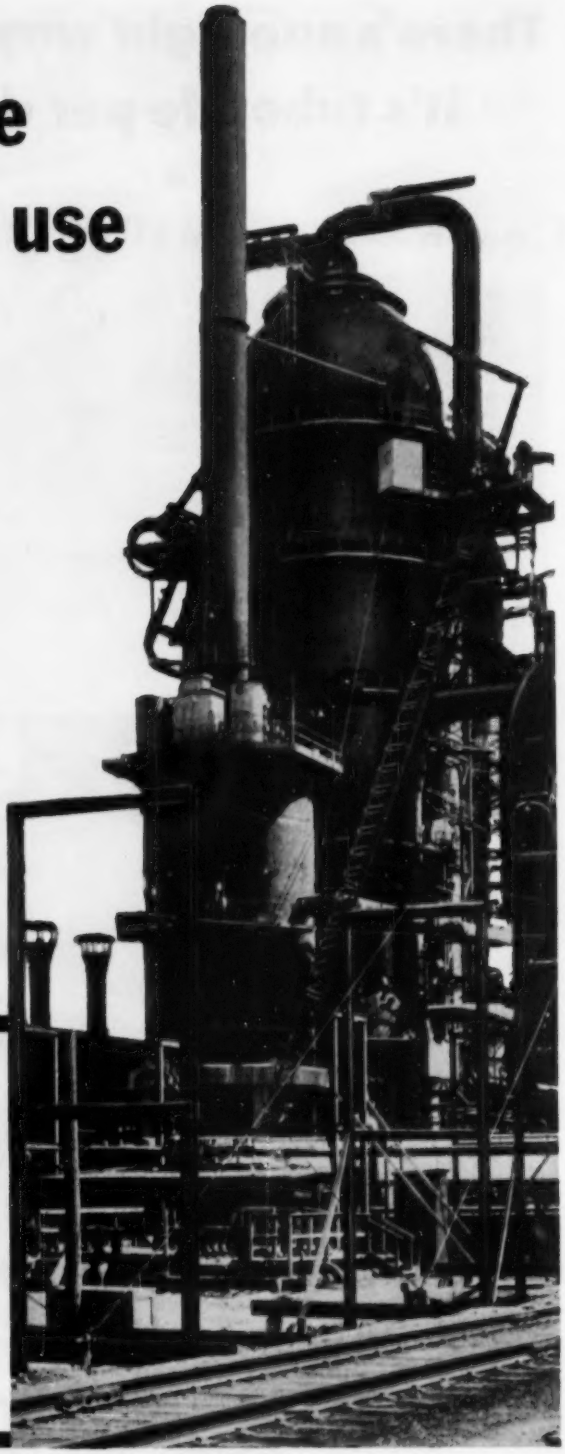
For more data on advertised products, use Readers' Service Cards, last page.

# How many of these concretes can you use in your refinery?

Solve heat, corrosion and insulation problems in your refinery with concretes made with Lumnite calcium-aluminate cement. Placement is fast and easy—by plastering, casting or guniting. You'll make rapid repairs because special Lumnite-made concretes reach service strength within 24 hours!

Chances are *all five* of Lumnite-made industrial concretes can save time and money for you. Check the list below to see where each one can do the best job in *your* refinery.

For even greater convenience, try castables. Packaged castable mixes containing Lumnite cement and selected aggregates assure the right concretes for a wide variety of refinery applications. All you do is add water, mix and place. Castables are made and distributed by leading manufacturers of refractories. Write today for detailed information on industrial concretes and castables made with Lumnite cement.



## 5 SPECIAL CONCRETES MADE WITH LUMNITE* CEMENT

1. **Refractory insulating concrete**—In strippers, rerun chambers, reactors, regenerators, fractional distillation and thermal alkylation units, bubble and flash towers, continuous-pressure stills.
2. **Abrasion-resistant refractory concrete**—Catalyst transfer and discharge lines, reforming chambers, gas coolers, reactor cyclones and transfer lines, regenerator cyclones and return lines.
3. **Refractory concrete**—For facings in refractory vessels with service temperatures to 2600° F.
4. **Corrosion-resistant and refractory insulating concrete**—Linings in regenerator exhaust lines, stacks, ducts.
5. **Corrosion-resistant concrete**—In linings for copper sweetening tanks, storage tanks, waste-disposal systems and acid trenches.

L-139

**UNIVERSAL ATLAS CEMENT COMPANY**

UNITED STATES STEEL CORPORATION SUBSIDIARY

100 PARK AVENUE, NEW YORK 17, N. Y.

*Albany • Birmingham • Boston • Chicago • Dayton • Kansas City • Milwaukee Minneapolis • New York • Philadelphia • Pittsburgh • St. Louis • Waco*

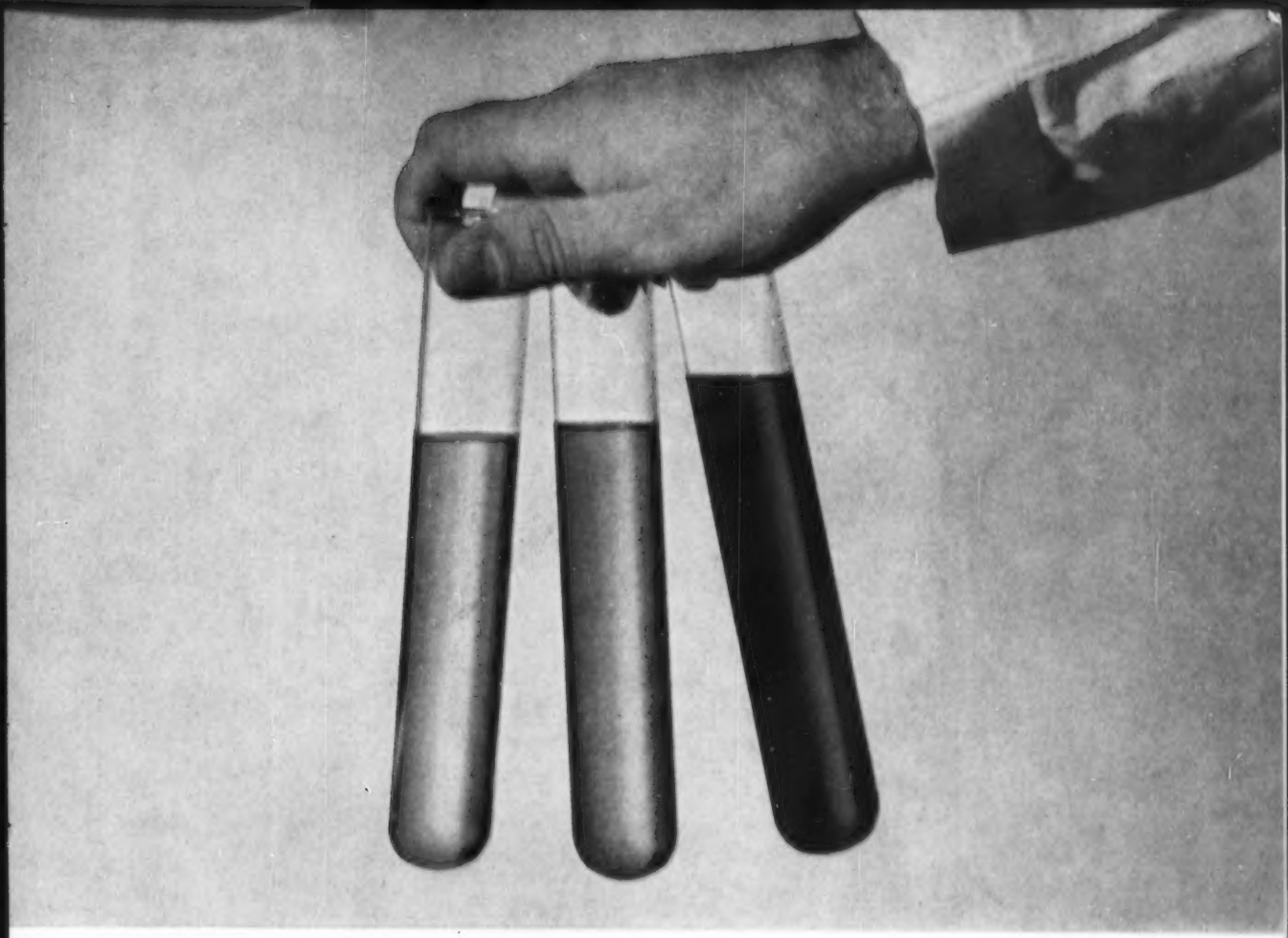
*"LUMNITE" is the registered trademark of the calcium-aluminate cement manufactured by Universal Atlas Cement Company.

**Atlas® Lumnite Cement**

**FOR INDUSTRIAL CONCRETES**

REFRACTORY • INSULATING • OVERNIGHT • CORROSION-RESISTANT

United States Steel Hour—Televised on alternate Wednesdays—See your local newspaper for time and station.



## Shipped 2,000 miles and Stored 4 months...

# NALCO-STABILIZED FUEL OIL STAYS CLEAR

This blended straight-run and cat-cracked fuel oil was refined in Texas. Unstabilized, it degraded to N.P.A. Color 4.0 after tanker shipment to New York and subsequent 4 months storage. How the same oil, Nalco stabilized, withstood the trip and storage is dramatically shown in the unretouched color photo, above.

At left, a refinery fresh sample has N.P.A. Color 1.5. Center, Nalco-stabilized sample has N.P.A. Color 2.0 after 4 months. Right, untreated sample has N.P.A. Color 4.0 after 4 months.

Here is real Nalco protection against color degradation . . . protection that has the bonus value of effective sludge prevention. Nalco Fuel Oil Treatment adds up to *better fuel oil salability*, regardless of fuel types, storage or handling problems. Full data are available, now. Call or write for Technical Data Sheets on Nalco stabilizers.

**NATIONAL ALUMINATE CORPORATION**

6216 West 66th Place • Chicago 38, Illinois • POrtsmouth 7-7240

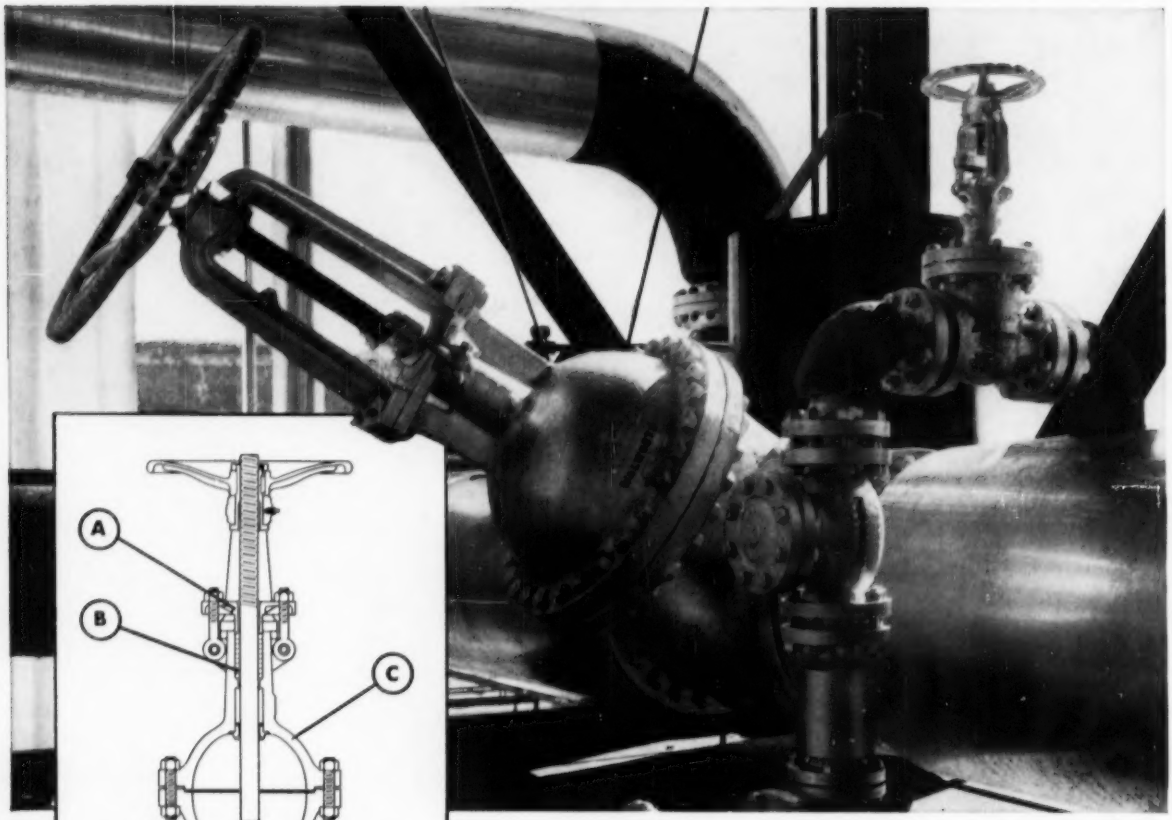
CANADA: *Alchem Limited, Burlington, Ontario*

NORTHWESTERN UNITED STATES, HAWAII AND ALASKA
*The Flox Company, Inc., Minneapolis 3, Minnesota*

ITALY: *Nalco Italiana, S.p.A.* SPAIN: *Nalco Espanola, S.A.*
WEST GERMANY: *Deutsche Nalco-Chemie GmbH.*

*nalco*•

**PRODUCTS**...SERVING INDUSTRY THROUGH PRACTICAL APPLIED SCIENCE




## Walworth Series 150 and 300

# CAST STEEL GATE VALVES OFFER YOU THESE FEATURES

### for 'round-the-plant service

**(A) GLANDS:** Clearances between the gland and stuffing box, and gland and stem, are such that the stem cannot be scored even if the gland is pulled down unevenly.

**(B) DEEP STUFFING BOXES:** More than adequate in all sizes (2″ to 24″) to assure tightness and maximum packing life.

**(C) BONNETS AND BODIES:** Engineered to exceed the requirements of all applicable codes and standards. They are tough, durable, dependable.

**(D) INTEGRAL GUIDE RIB FACES IN BODY:** Machined to insure accurate centering of the gate.

**(E) STURDY SEAT RINGS:** Bottom-seated so that no recess exists at the back of the ring to cause turbulence, erosion and pressure drop.

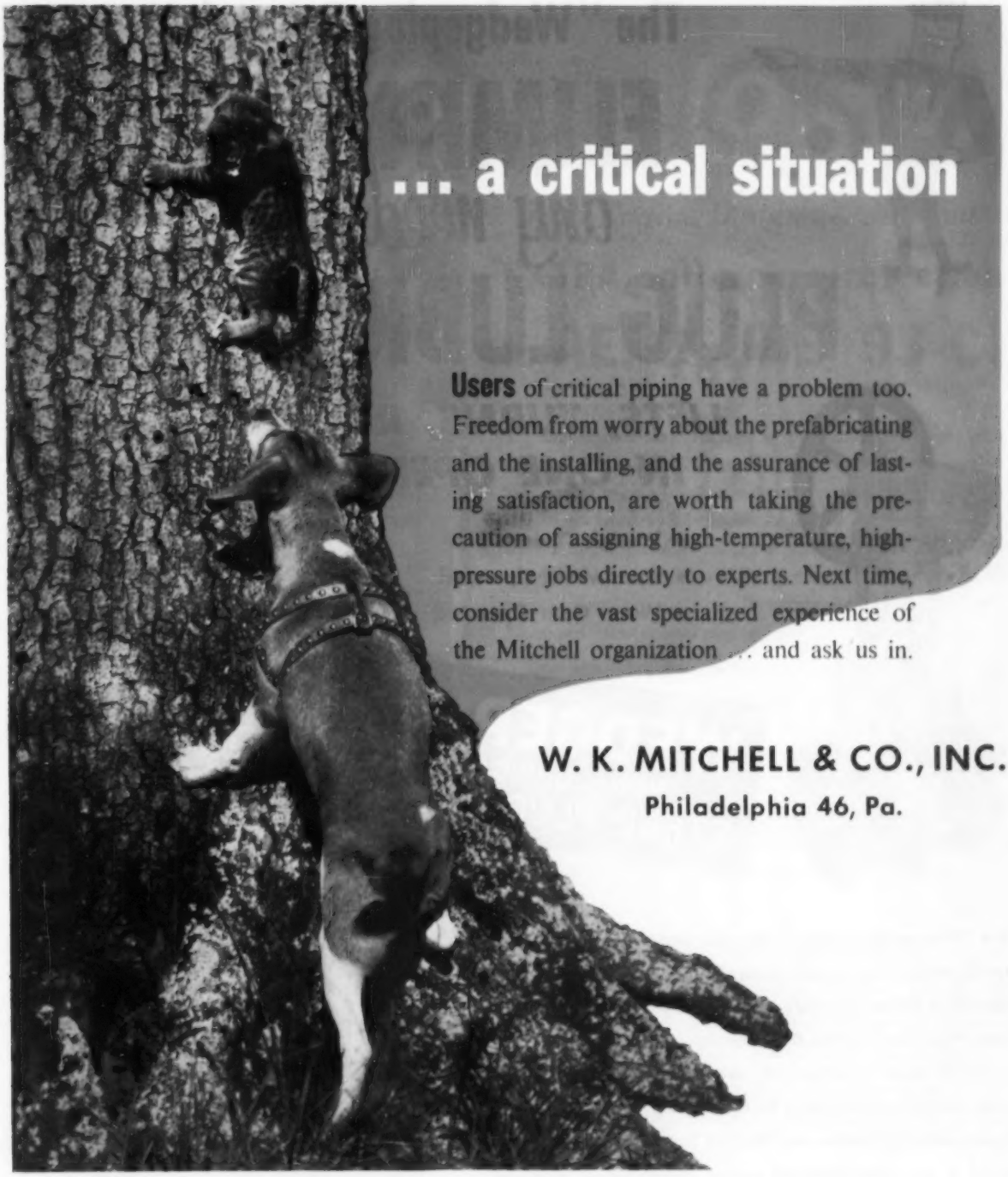
**(F) STREAMLINED PORTS:** Permit unobstructed flow which results in minimum pressure drop and reduces the possibility of erosion.

Walworth Cast Steel Gate Valves can be furnished with either flanged ends or butt welding ends. Roller bearing yokes are available on the larger sizes. On valves 4 inches and larger, by-passes can be furnished. Walworth Cast Steel Gate, Globe and Check Valves from Series 150 to 2500, are available. For Series 600 and higher, we recommend Walworth Pressure Seal Cast Steel Valves. See your Walworth Distributor or write to Walworth for complete information.

# WALWORTH

60 East 42nd Street, New York 17, New York

SUBSIDIARIES: ALLOYCO ALLOY STEEL PRODUCTS CO. CONOFLOW CORPORATION M&H M & H VALVE & FITTINGS CO. SW SOUTHWEST FABRICATING & WELDING CO., INC. WALWORTH COMPANY OF CANADA, LTD.



# ... a critical situation

**Users** of critical piping have a problem too. Freedom from worry about the prefabricating and the installing, and the assurance of lasting satisfaction, are worth taking the precaution of assigning high-temperature, high-pressure jobs directly to experts. Next time, consider the vast specialized experience of the Mitchell organization ... and ask us in.

**W. K. MITCHELL & CO., INC.**
**Philadelphia 46, Pa.**

*WESTPORT JOINT*
(PATENTED)

# *MITCHELL PIPING*
SINCE 1899

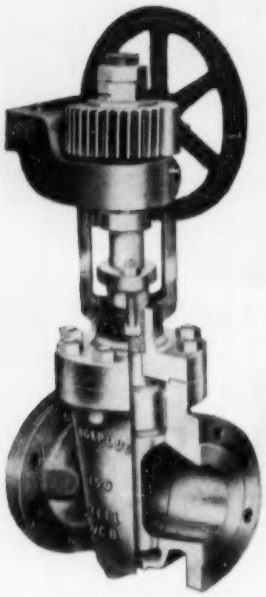
**PIPING FABRICATORS AND CONTRACTORS**



For more data on advertised products, use Readers' Service Cards, last page.

The "Wedgeplug Principle"

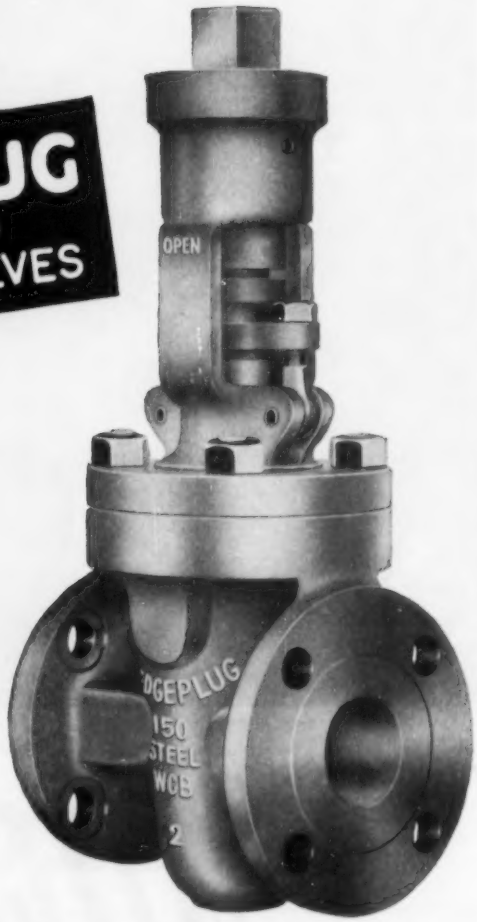
# ELIMINATES any need for PLUG LUBRICATION



## LIFTS, TURNS, RE-SEATS IN ONE OPERATION

- Wrench Operated
- Handwheel Operated
- Worm Gear Operated

**WEDGEPLUG**
NON-LUBRICATED
STEEL PLUG VALVES




The "Wedgeplug Principle"—lift, turn, and re-seat—assures the quick, positive, trouble-free action of Wedgeplug Non-Lubricated Steel Plug Valves at a wide range of temperatures—from Petroleum "Cat Cracking" to the handling of Liquid Oxygen. The ability to perform satisfactorily at these extreme temperatures gives double assurance that Wedgeplug Valves will be trouble-free in ordinary service. And, the fact that the plug is non-lubricated is an extra safeguard against contamination, wherever this is a factor.

**WEDGEPLUG VALVE COMPANY, INC.**
*An Affiliate of*
**STOCKHAM VALVES & FITTINGS**
GENERAL OFFICES AND PLANT • BIRMINGHAM 2, ALA.

**WEDGEPLUG PERFORMANCE SAVES MONEY FOR YOU**

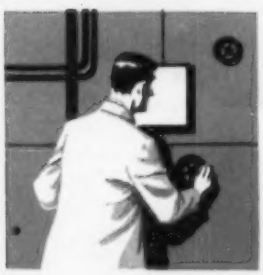
*Our Lubrication Engineers worked with Engine Designers, then put*

## EXTRA anti-wear protection in AEROLUBE® 93-C!

Top anti-wear characteristics are specifically formulated into Cyanamid AEROLUBE 93-C inhibitor to give the extra protection required in engine break-in, severe service or other problem conditions faced by lubrication engineers. This concentrated zinc dithiophosphate inhibitor safeguards stability—it is an excellent oxidation inhibitor that prevents formation of harmful peroxides and organic acids. It sharply reduces wear of valve lifters and other critical engine parts.

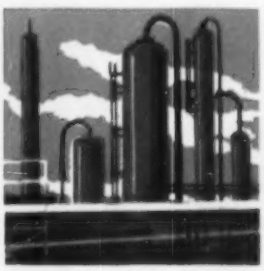
Zinc dithiophosphate has proved itself to be one of the most effective additives for commercial lube oils. Maximum wear resistance, oil stabilization and bearing protection, demanded by modern engines, have been built into Cyanamid's AEROLUBE 93-C.

Light color and compatibility with lube stocks and other additives, make AEROLUBE 93-C outstanding for use in premium oil products—for regular use as well as initial fill.



### AERO® HDS CATALYST

In modern hydrodesulfurization processes, Cyanamid's new AERO HDS Catalyst contributes highest available volume activity and excellent mechanical properties. Cyanamid's specialized catalyst know-how may be helpful in initiating or improving your hydro-treating operation.



### REFINING RESEARCH

At Stamford, Connecticut, the Refinery Chemicals Department of Cyanamid maintains laboratories unsurpassed in the refining field for basic research and development in catalysts and other refinery chemicals. As a part of extensive research and pilot plant facilities, specialized equipment and methods—such as the electron microscope and vapor-phase chromatography—are used to develop information leading to improved products which give optimum performance under field conditions.

*Our field men are constantly absorbing new developments at the research, development and operating levels. In this way, your Cyanamid man keeps abreast of the petroleum industry's dynamic technology and can offer a valuable technical service to refiners.*

CYANAMID

AMERICAN CYANAMID COMPANY
REFINERY CHEMICALS DEPARTMENT
30 Rockefeller Plaza, New York 20, N. Y.

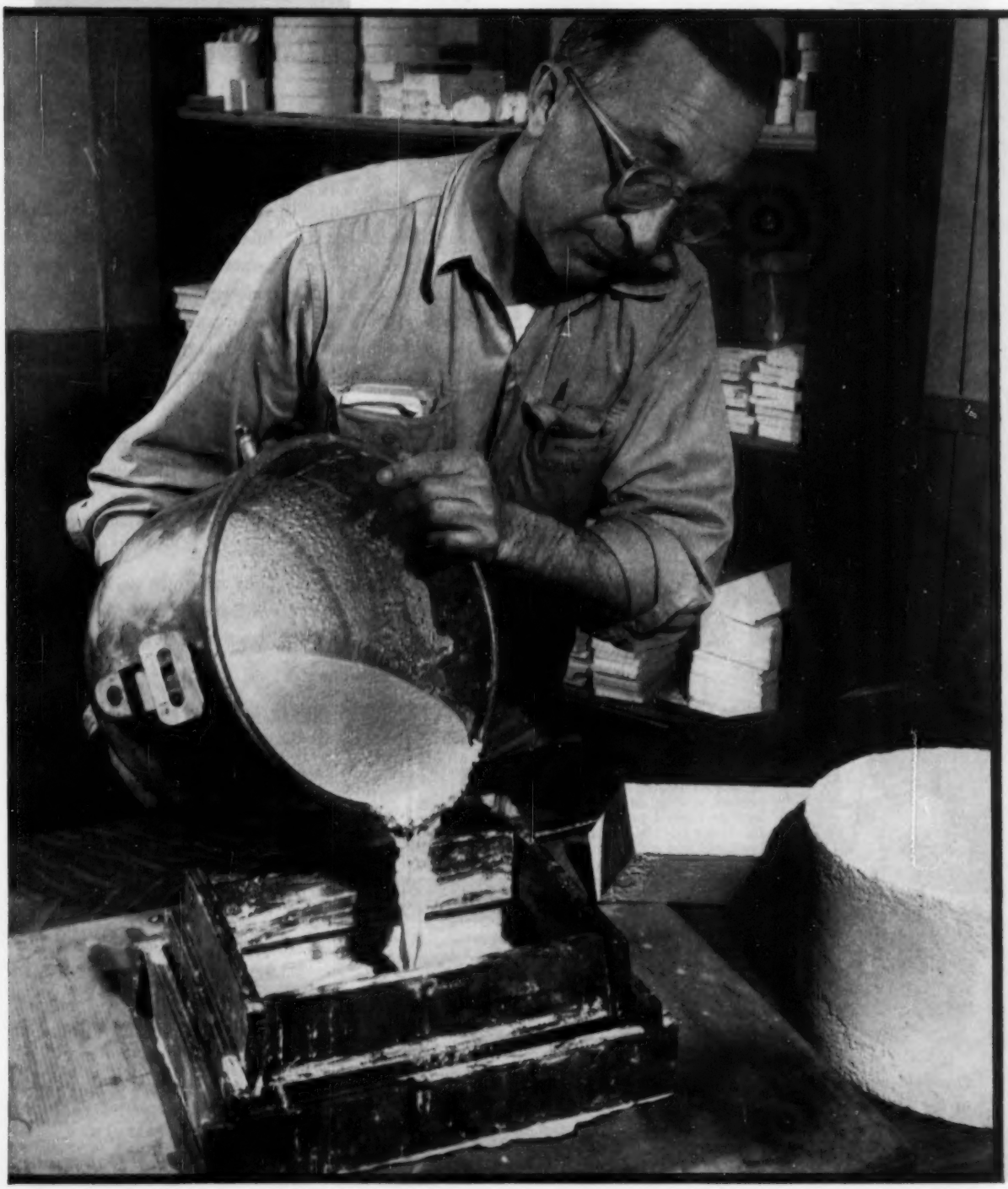
In Canada: North American Cyanamid Limited, Toronto and Montreal



For more data on advertised products, use Readers' Service Cards, last page.

*Two vital newcomers for your furnace operations*

# New ALUNDUM*



42 For more data on advertised products, use Readers' Service Cards, last page.

# Castables...33-I and 33-HD

## *are easy to use, protect up to 3300° F, eliminate costly pre-fired shapes and bring you other big savings*

New, Norton-engineered 33-I and 33-HD ALUNDUM Castables offer exceptional advantages to the ceramic, metals and chemical processing industries where high temperature furnaces are used. These new high temperature Castables are designed for working face areas and back-up in such furnaces.

Both types are easy to mix and work. Both require only inexpensive forms for making simple or intricate shapes. Both dry fast, enabling you to prepare furnace areas quickly. And their ability to provide new highs in temperature protection, to replace many pre-fired shapes, and to assure long trouble-free service gives you steady, worthwhile savings.

### *ALUNDUM 33-I Insulating Castable*

is made up primarily of pure aluminum oxide bubbles. These countless tiny bubbles form a network of air spaces which are light in weight and provide excellent insulation, even at highest commercial temperatures. These qualities make 33-I ideal for lightweight furnace construction, where it stands up under radiated high temperatures or erosion by mild flame and gas. It gives excellent protection to service face applications, and as a back-up for ALUNDUM 33-HD Castable or for high purity pre-fired ALUNDUM shapes.

### *ALUNDUM 33-HD Heavy Duty Castable*

is also chiefly composed of pure aluminum oxide, but of dense grain material, which makes it heavier duty than 33-I. In fact, 33-HD is the most efficient Castable for forming dense monolithic surfaces in the construction of many types of high temperature furnaces, especially where operating conditions are severe.

**Characteristics of ALUNDUM Castables**

| | 33-I | 33-HD |
|---|---|---|
| Density (as cast and dried) | 100 lbs. per cu. ft. | 170 lbs. per cu. ft. |
| Water added per 100 lbs. | 18 pts. | 11 pts. |
| Stiffens | 1 hr. | 1 hr. |
| Initial set | 4 hrs. | 4 hrs. |
| Final set | 18-24 hrs. | 14-24 hrs. |
| Shrinkage (as cast) | 0% | 0% |
| Grain size | 6F | 6F |
| Chemical analysis — $Al_2O_3$ | primarily | primarily |
| $SiO_2$ | <0.1% | <0.10% |
| $Fe_2O_3$ | <0.1% | <0.15% |
| Maximum hot face temperature | 3300°F | 3300°F |

### *Get all the facts*

A new Norton folder on ALUNDUM 33-I and 33-HD Castables is now ready to be sent to you. It gives you all the information you want on these new Castables — describes and illustrates exactly how you can mix and work them, and contains interesting charts of their linear shrinkage, modulus of rupture and thermal conductivity. These facts tell you just how you can improve your high temperature furnace operation, at lower costs. Write for your free copy to NORTON COMPANY, Refractories Division, 471 New Bond Street, Worcester 6, Mass. *Canadian Representative:* A. P. Green Fire Brick Co., Ltd., Toronto, Ontario.

NORTON

REFRACTORIES

*Engineered... Rx ...Prescribed*

*Making better products . . . to make your products better*

*Norton Products:* Abrasives • Grinding Wheels • Grinding Machines • Refractories

*Behr-Manning Products:* Coated Abrasives • Sharpening Stones • Behr-cat Tapes

*Trade-Mark Reg. U. S. Pat. Off. and Foreign Countries



For more data on advertised products, use Readers' Service Cards, last page.

The **REFINERY ENGINEERING** Company's horizons are greatly expanded. Treco is now in position to offer engineering, design and construction of refineries, chemical plants, ore processing, secondary recovery and gas processing facilities on a world-wide basis.

The company has greatly enlarged engineering resources, research and development laboratories and a rapidly expanding staff. This enables The **REFINERY ENGINEERING** Company to offer a *complete service* to nearly all types of industries.

Treco has just produced a brochure which shows the Company's facilities with photographs of completed projects. A copy will be mailed you promptly upon request on your company's letterhead.

TRECO

A DIVISION of VITRO CORPORATION of AMERICA

*The* **REFINERY ENGINEERING** *Company*

NEW YORK TULSA TORONTO

*Now—the Plant You Dream about...*

# Maintenance-Free because of Aluminum

**Here's Why:**

Aluminum resists rust and corrosion due to chemicals, gases, plant atmospheres, and coastal environments. You save the expense of painting and enjoy the natural bright appearance of this long-lasting metal. You save on replacement of parts destroyed by corrosion.

**Build with Aluminum Throughout**

**Aluminum Structurals** give you strengths equal to structural steel with only ⅓ the weight. Ideal for framework and supports.

**Aluminum Jacketing** provides maintenance-free beauty plus the benefits obtained from natural insulation.

**Aluminum Tread Plate** is strong and lightweight, will not spark, resists rust and corrosion.

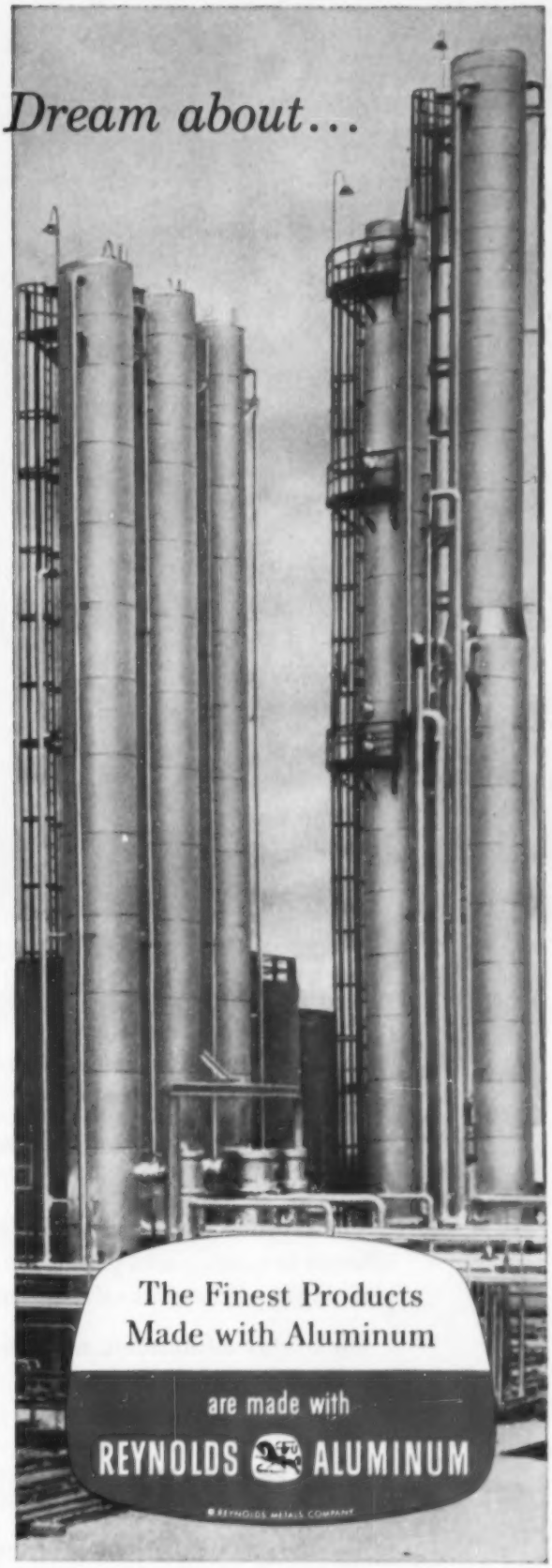
**Aluminum Heat Exchanger Tubing** offers lower initial cost, provides lower service costs.

**Aluminum Accessories** for gratings, railings, ladders and walkways.

**Aluminum Process Pipe** will not contaminate refined liquids and gases.

**Get Complete Details Today**

Call the Reynolds office listed under "Aluminum" in your classified telephone directory. Or write to *Reynolds Metals Company, P. O. Box 1800-CT, Louisville 1, Kentucky.*






For more data on advertised products, use Readers' Service Cards, last page.

Two of the world's largest urea plants have been designed and constructed by Foster Wheeler. They have a combined capacity of 400 tons per day of urea prills.

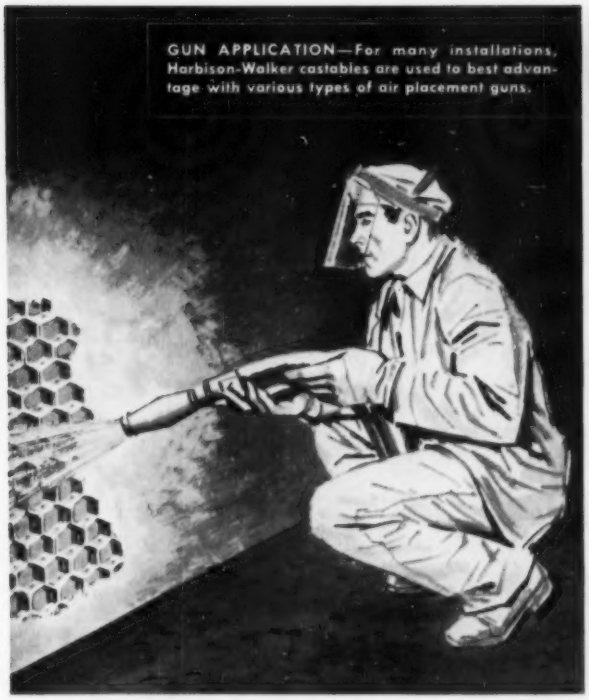
The design of these plants followed the most advanced technology aimed at producing a high-quality product at minimum cost.

The experience gained in the solution of process and mechanical problems inherent in tonnage urea production is available to manufacturers planning to produce this valuable synthetic.

For further information, write to *Foster Wheeler Corporation, 165 Broadway, New York 6, N. Y.*

**FOSTER WHEELER**

NEW YORK • LONDON • PARIS • ST. CATHARINES, ONT.



GUN APPLICATION—For many installations, Harbison-Walker castables are used to best advantage with various types of air placement guns.

TROWELLING—This method is preferred for some applications and the excellent working qualities of Harbison-Walker castables make them easy to use and to secure uniform durable linings.

*For refractory linings that last longer...*
*specify HARBISON-WALKER*

## H-W EXTRA STRENGTH CASTABLE

## H-W 56 LIGHTWEIGHT CASTABLE

Used together as illustrated, these two Harbison-Walker castable refractories form a lining that withstands the erosion, temperatures and pressures of refinery units, and provides highly effective insulation that reduces heat losses. Both products are particularly suited for service in catalytic cracking regenerators, reactors, catalyst feed lines and other units. They can be trowelled, poured like concrete, tamped or applied with air guns.

Write for complete information about these refinery-proved Harbison-Walker castable refractories.

Cross-sectional view shows H-W 56 Lightweight (insulating) Castable next to the regenerator shell, with H-W Extra Strength Castable superimposed for the working lining, where its high strength, excellent erosion resistance and low coefficient of expansion all contribute to long service life.

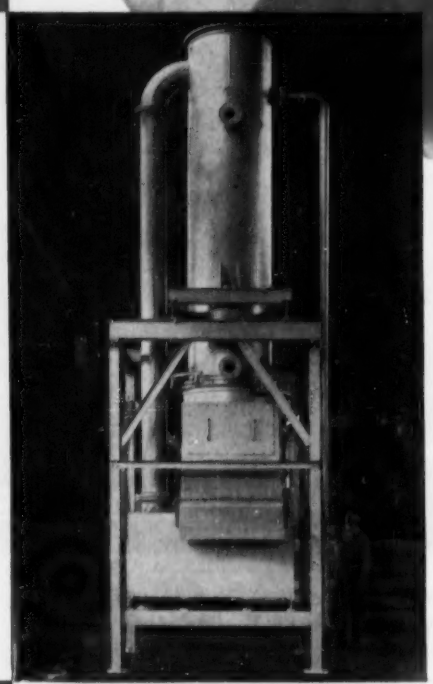
**Harbison-Walker Refractories Company**
AND SUBSIDIARIES
*World's Most Complete Refractories Service*
GENERAL OFFICES: PITTSBURGH 22, PENNSYLVANIA


For more data on advertised products, use Readers' Service Cards, last page.

# "What is your processing problem?"

*this machine congeals, molds and discharges automatically

*If your process involves a liquid that will solidify when cooled.... ....this machine can do it....then discharge and size the substance.... all automatically



If you have a processing problem, perhaps the Vogt Automatic Tube-Type Molding Machine will provide the answer because it will form and size any liquid that will solidify when cooled, and will discharge by gravity upon heating.

Now in use by major chemical companies, these units have achieved tremendous savings in labor while producing a more uniform product. Also, since the process involves "freezing" or solidifying the substance while it circulates through tubes, the quality of the product is often superior to that of the original charge.

The wide range of uses to which Vogt Tube-Type Molding Machines have been adapted indicates their definite value in the chemical processing field. Adaptation possibilities are virtually unlimited and you may request detailed technical information from our engineers without obligation.

*Address Dept. 24A-RIPR*

Vogt

Automatic Tube-Type

# MOLDING MACHINE

**HENRY VOGT MACHINE CO., LOUISVILLE, KY.**

SALES OFFICES: New York, Philadelphia, Chicago, Cleveland, Cincinnati, St. Louis, Dallas, Charleston, W. Va., San Francisco

# HOUDRY NOBLE METAL CATALYSTS

## for reforming, hydrogenation, and dehydrogenation

Houdry Platinum and Palladium Catalysts on hard alumina base are manufactured to obtain high, uniform hardness. They have proven process efficiency in all of the following processes:

REFORMING

DEHYDROGENATION • HYDROGENATION

ISOMERIZATION • DEHYDROISOMERIZATION

**HOUDRY**

**PROCESS CORPORATION**

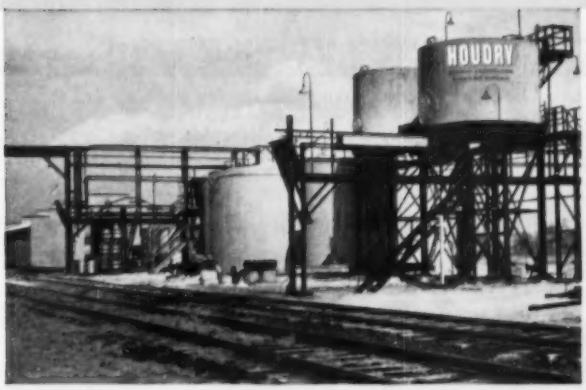
***Pioneer in Catalysis***

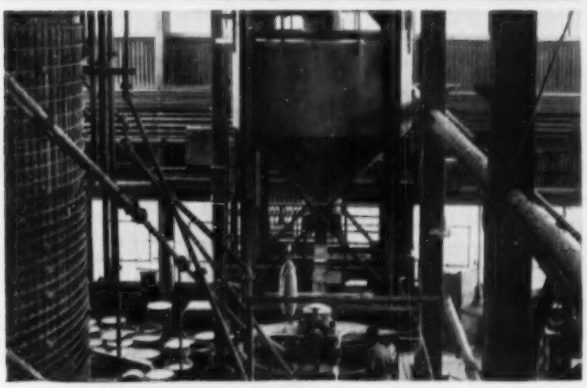
1528 Walnut Street, Philadelphia 2, Pa.

### TYPICAL PROPERTIES

| | PLATINUM CATALYSTS | | PALLADIUM CATALYSTS | |
|---|---|---|---|---|
| SERIES | A | A | A | B |
| GRADE | 100S | 200SR | 100SR | 100S |
| Metal content, wt. %, nominal | 0.5 | 0.5 | 5.0 | 0.5 |
| $Na_2O$, wt. % min. | 0.1 | 0.1 | 0.1 | 0.1 |
| Surface Area, $m^2/g$. | 80 | 145 | 125 | 80 |
| Bulk Density, kg./l | 0.84 | 0.84 | 0.88 | 0.86 |
| Knife-edge Hardness, g. | 5,000 | 7,900 | 4,500 | 4,500 |

Houdry Chemicals Division will manufacture pelleted type catalysts to specifications . . . and will also assist in developing catalysts for special requirements. Additional information will be sent on request.





The Houdry Paulsboro, N. J., plant, built in 1940, was the first commercial plant in the world to produce synthetic cracking catalysts. In the past 16 years, facilities have been expanded to produce a general line of pelleted catalysts.



For more data on advertised products, use Readers' Service Cards, last page.

CONOCO

STANDARD

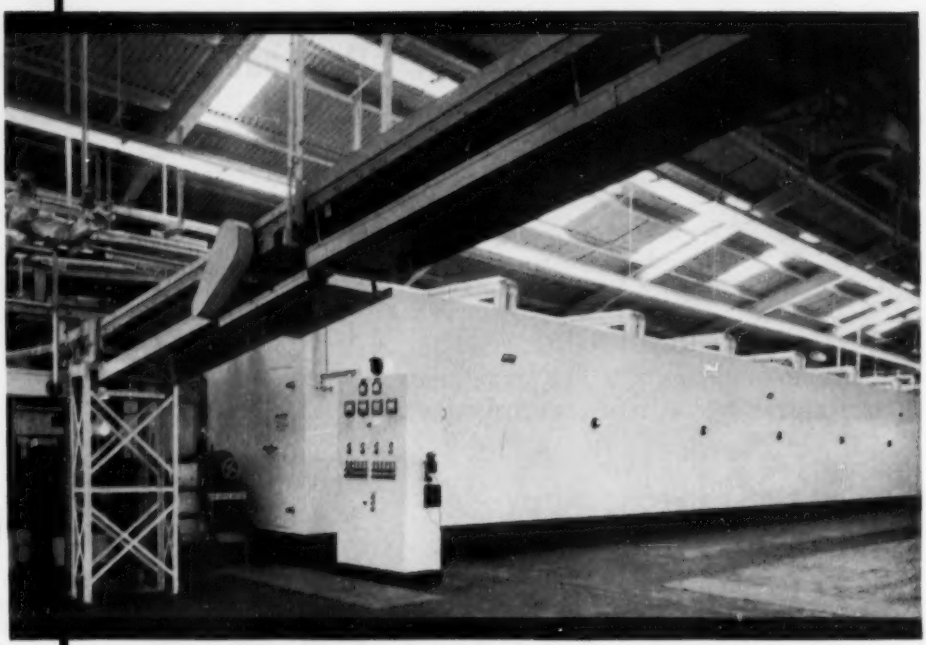
SINCLAIR OILS

Esso

GULF

STANDARD

CITIES SERVICE



# New profits from Wax

**MORE AND MORE** refiners are slabbing wax faster, more economically with GREER Wax Moulders because Greer Moulding plants save labor and space . . . boost production . . . improve quality control.

**ONE-MAN OPERATION** . . . deposits, cools and demoulds cakes completely automatically. Virtually eliminates 85% of wax slabbing labor costs.

**SAVES VALUABLE FLOOR SPACE** . . . Packs your entire slabbing operation into floor space only 10 to 25% of that required by batch processes of equal capacity.

**EXACT, DEPENDABLE WEIGHT CONTROL** . . . Now you can mould cakes within ½ of 1% of desired weight — continuously, automatically. Automatic moulding means improved appearance and cleanliness of cakes, too.

**NEW CHOICE OF SIZES** . . . Ten-pound Slab Machine now available in two models from 2500-7500 pounds/hour, and 10,000-15,000 pounds hour.

WRITE for informative 9-page Bulletin 51-2

# J. W. GREER COMPANY

WILMINGTON, MASSACHUSETTS

*Sales Engineering Offices: Chicago, Ill., San Francisco, Calif.*

GREER

# ANNOUNCING Catalin ANTIOXIDANTS

## Commercial Quantities Immediately Obtainable!

Catalin Antioxidants AC-1 and AC-3 are now in full production at the Catalin plant in Fords, N. J.

Manufactured to the *highest commercial* specifications and produced under rigid quality controls, Catalin Antioxidants are available in uniformly sized white crystals or in solution.

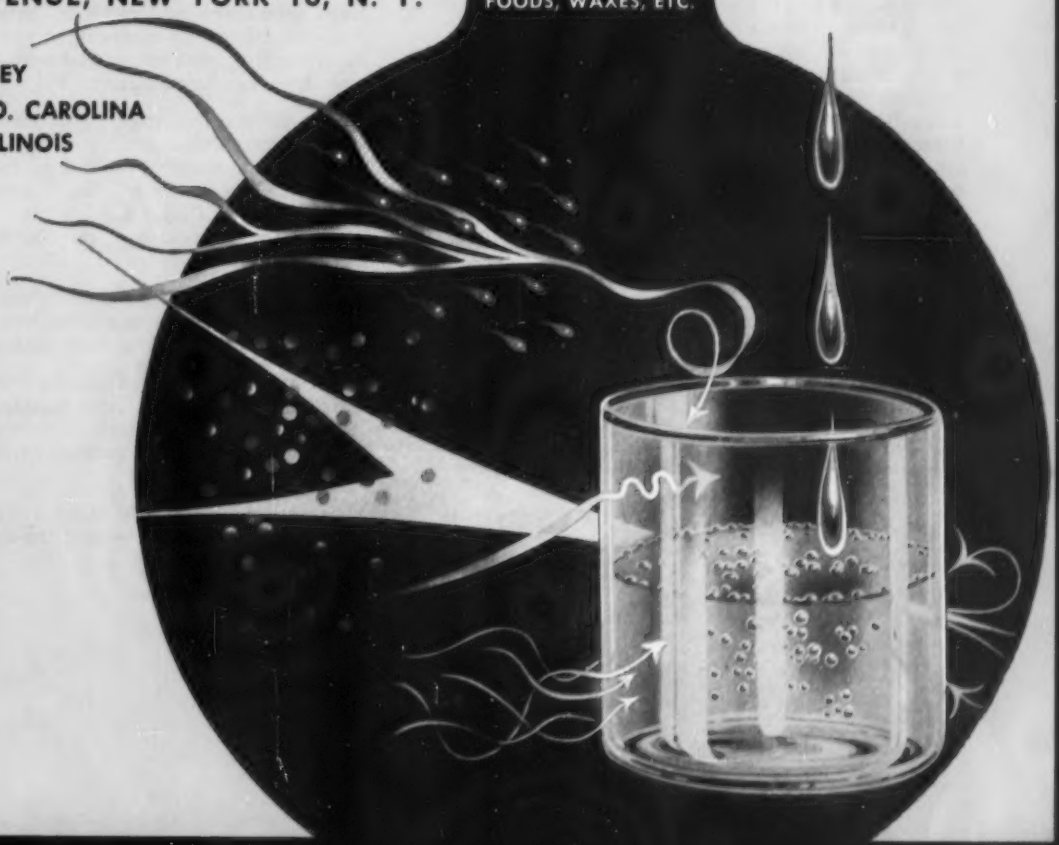
Non-toxic and non-discoloring, they combat product *breakdown* or *change* due to oxidation. Effective in concentrations of less than .005 to 2.00 per cent by weight, Catalin Antioxidants add a negligible little to product-cost but much to product-security.

Should you therefore be exploring the subject and use of inhibitors, we commend the multiple advantages of Catalin Antioxidants to your consideration. Samples, literature and technical assistance wait upon your request. Inquiries invited.

TECHNICAL GRADE
**AC-1**
*— for*
GASOLINES,
JET FUELS,
TURBINE, INSULATING,
MOTOR AND
LUBRICATING OILS.
RUBBER.
INDUSTRIAL FATS
AND OILS.
PLASTICS,
POLYOLEFINS, ETC.

FOOD GRADE
**AC-3**
*— for*
EDIBLE FATS AND OILS,
FOOD WRAPPINGS,
PHARMACEUTICALS,
COSMETICS,
FOODS, WAXES, ETC.

ALKYLATED CRESOL



**CATALIN CORPORATION OF AMERICA**
ONE PARK AVENUE, NEW YORK 16, N. Y.

Plants:
FORDS, NEW JERSEY
THOMASVILLE, NO. CAROLINA
CALUMET CITY, ILLINOIS

Catalin

In addition to Styrene, Polyethylene and Nylon Molding and Extrusion Compounds, Catalin products include Antioxidants and a wide range of Urea, Phenolic, Cresylic, Resorcinol and Melamine resin formulations.

# TECHNIQUES *and* TOOLS

# MAKE THE DIFFERENCE IN WESTERN HEAT EXCHANGERS

The manufacture of Western heat transfer equipment is characterized by two important factors: (1) employing the latest and best data available in establishing the actual needs of our customers quickly and accurately; (2) employing the same care and attention to detail in the fabrication of the equipment required.
Western Supply Company renders a *complete service* to each customer — research, design, engineering and fabrication — resulting in equipment of exceptional quality at a fair price, and built for long-life economy.
Your heat transfer requirements — present or future — deserve the attention of Western *specialists* in this field. We'll appreciate your inquiry.

In the *thermal rating* of heat transfer requirements, Western engineers have developed a technique which is actually a *consulting service*, working closely with customers to arrive at the best and simplest solution of their needs.

*Thus,* each Western exchanger is sized to give the most economical unit for the job, and reflects the experience gained in working equally closely with other customers with similar problems.

The Western "technique" also recognizes the importance of completing your heat exchanger file quickly, thereby allowing you to proceed with other operations.

*For instance,* when standard floating head, U-tube or fixed tube sheet exchangers are ordered from Western, you can depend on receiving drawings *within 7 to 10 days,* enabling you to proceed with piping and foundation drawings immediately.

In the fabricating stage, Western uses only the most modern production tools and equipment, assuring the utmost in production control in the building of your heat exchangers. Such quality controls as controlled torque tube rolling, weld x-ray, Magnafluxing and hydrostatic testing assure the consistent high standard of Western exchangers.

ASME code standards represent the *minimum* requirement for Western heat exchangers, but on *each* unit, Western builds the *best heat exchanger possible.*

*Thus,* in the instance of careful tube hole preparation and controlled torque tube rolling, a given Western Exchanger can be retubed more often for greater savings for our customers, because of these high standards of production.

Techniques and tools *do* make a difference in thermal and mechanical design — and the difference is in your favor at Western!

**WESTERN**
**HEAT EXCHANGERS**

WESTERN SUPPLY COMPANY
P. O. BOX 1888 • TULSA, OKLAHOMA

HUDSON-RUSH COMPANY — 753 Gladstone Blvd., Shreveport, La.
130 Casa Linda Plaza, Dallas, 18, Tex.
P. O. Box 3151, Amarillo, Tex.

PROCESS INSTRUMENTS & EQUIPMENT CO. — North Bldg., Charleston, W. Va.

H. W. SEVERANCE — 2416 Frankfort Ave., Louisville, Ky.

# 2 TO 1 *in Your favor*

## CHAPMAN MOTOR UNITS

**...for Valves, Floorstands, and Sluice Gates**

It's a matter of simple mathematics. Take any one of Chapman's Motor Units and look it over carefully. You'll find approximately half as many parts as with any other make. This means the chances of cutting maintenance costs are two to one in your favor.

The odds can be even better. With Chapman Motor Units, you not only get simplified design, you also get sturdy construction and smooth, accurate performance over a longer period of time. There's no drift. Backlash is low. An accurate micrometer-controlled limit switch keeps seat tightness at any predetermined level.

Two points more — with Chapman Motor Units there's no trouble with either operating positions or operating conditions. Rugged stub-tooth gears require no grease or oil . . . operate at any angle . . . and the complete unit is not only weatherproof. It's *steam tight*.

Even on installation there's a chance of saving money with Chapman Motor Units. When used with floorstands they are completely wired at the factory . . . ready to connect and work. It's an easy, simple, low-cost job.

Chapman Motor Units for valves, floorstands, and sluice gates are outlined in full in our Catalog 51. If you don't have it, write for it, right now.

**THE CHAPMAN VALVE MANUFACTURING CO.**
**INDIAN ORCHARD, MASS.**


For more data on advertised products, use Readers' Service Cards, last page.

MEMO Tues. P.M.

Joe-
got a Rush Job-
order me full set of
those little Ridgid
drop-head dies & like-
Hawk

Every RIDGID Pipe Tool TESTED individually before shipment

RIDGID 00R
⅛" to 1"

RIDGID 111R
⅛" to 1¼"

RIDGID 12R — ⅛" to 2"

RIDGID

## ⅛" to 2" Drop-Head Threaders

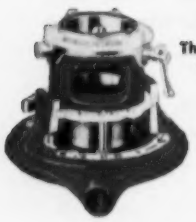
### Handiest darned ratchet threaders you ever used!

Really handy, time savers, easy to use. Pick up the size head you need, snap it into the ratchet ring . . . and start threading! Heads can't fall out. Dies reverse easily for close-to-wall threading. Conduit and special dies available. Free carrier with sets. For perfect threads easily and long service, buy 'em at your Supply House.

Carrier Free with Sets

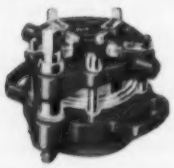
**Bolt Threaders, too— ask for RIDGID 00R-B, same easy-work advantages as drop-head pipe dies.**

**Whole Line of RIDGID Pipe Threaders Offers You Extra-Easy Threading**



**RIDGID**
Jam-proof 65R
Threads 1" to 2" pipe with 1 set of dies.

**RIDGID**
504 Threader
for power drive use—threads 1" to 2" with 1 set of dies.



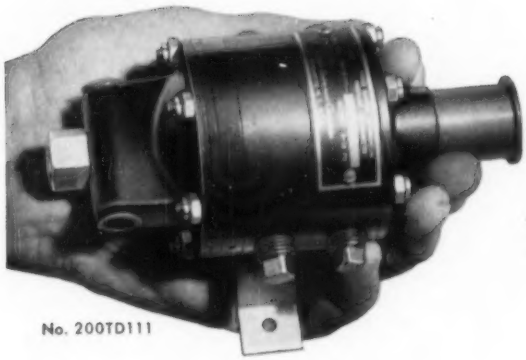
**RIDGID**
4P Geared Threader
2½" to 4" pipe—extra-easy handling, no upkeep.

**RIDOIL**
Top Quality Sulphur-Lard Thread-Cutting Oil

RIDGID
Work-Saver Pipe Tools

**The Ridge Tool Company • Elyria, Ohio, U. S. A.**

# "That new Taylor Instrument's saving us money already!"



No. 200TD111

## He's talking about the new Taylor low-cost Flow Transmitter!

THE reason he can spot the savings so quickly is that the No. 200TD111 Fixed Range Differential Pressure Transmitter is being used to measure departmental consumption of steam, air and water that previously went unchecked. That 3-pen recorder in the background shows at a glance how much is being used by a given department as a basis for apportioning costs. It's the remarkably low price of this new instrument that makes it such a practical cost accounting aid on applications hitherto considered marginal.

Measuring only 6½" x 3" and weighing only 4½ lbs., its simplified piping, force-balance construction and external adjustments make it easy to install and maintain. Calibration accuracy is better than 1%. Sensitivity exceeds 0.1%. Ranges 0 to 50, 100, 200 and 300 inches of water. Built for rough service and outdoor mounting.

Call your Taylor Field Engineer, or write for **Bulletin 98274.** Taylor Instrument Companies, Rochester, N. Y., or Toronto, Canada.

**DESIGN SPECIFICATIONS**

Diaphragm of Neoprene-impregnated Nylon.
Body material, brass.
Maximum working pressure: 150 psi.; temperature 150°F.
Air Supply pressure, 20 psi.
Air consumption, 0.10 standard cu. ft. per minute.
Output pressure range 3 to 15 psi.
Size 6½" x 3". Weight 4 lbs. 9 ozs.
All connections ¼" internal NPT.

*Taylor Instruments*
MEAN
ACCURACY FIRST
IN HOME AND INDUSTRY



For more data on advertised products, use Readers' Service Cards, last page.

# LADISH

## SEAMLESS

## *Multiple Outlet*

## FITTINGS

TO MARK PROGRESS

Typical fittings and piping layout of coils in a charge heater.

### LADISH DESIGNED 90° AND 45° ELBOWS

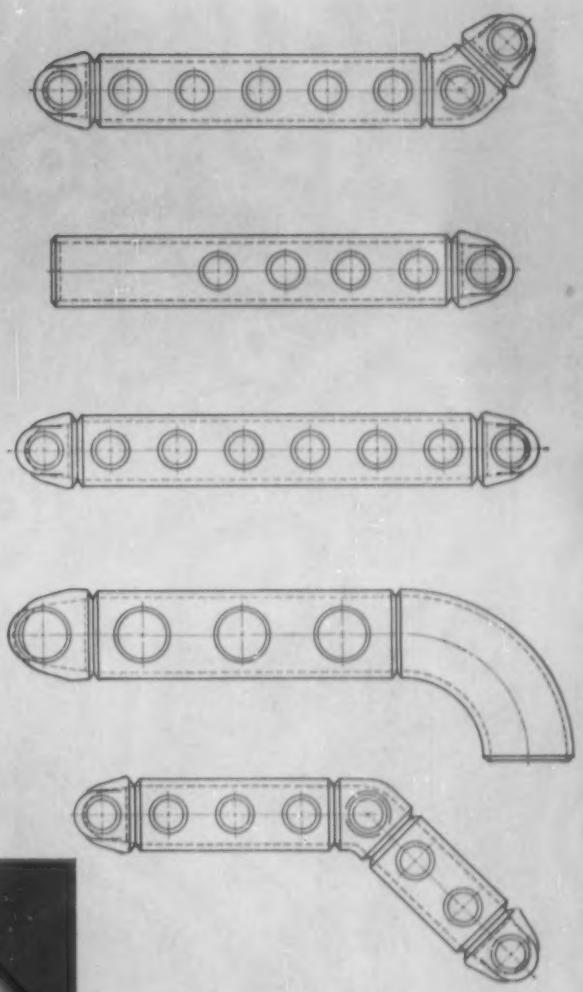
PATENT PENDING

Special die-forged Ladish 90° Reducing Heater Elbow provides a lower cost, easier to make up, final outlet and end closure. Obsoletes expensive, heavy-volume fillet weld required on straight blank-off design. Pressure drop is minimized and flow efficiency improved. Residue collecting pockets and stress risers at critical locations are eliminated. Provides ample clearance between fittings for ease of installation and more expansion allowance.

Ladish forged 45° Side Outlet Elbow effects positive savings in time and cost over the undesirable miter joint otherwise necessary. Eliminates time-consuming angle cutting and welding —then scribing, torching and nozzling-in of outlet directly over miter joint. Only two, easy-to-make circumferential butt welds required . . . deposition of weld metal at this critical juncture is minimized.

# IMPROVE FLOW EFFICIENCY ... SAVE PIPING ERECTION COST IN HEATER INSTALLATIONS

**Illustrated here are typical combinations of Ladish Multiple Outlet Fittings, 90° Reducing Heater Elbows and 45° Side Outlet Elbows produced to meet design requirements for heaters with varying flow cycles.**

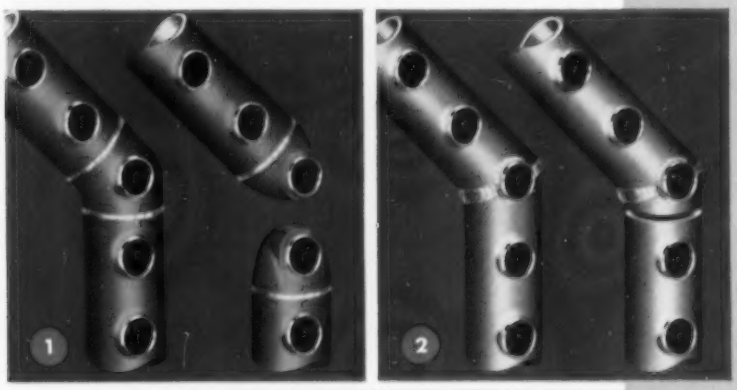


**SEAMLESS Multiple Outlet Fittings developed and produced by Ladish . . . offer you significant design advantages and installation and operational economies.**

**Only simple circumferential welds are required to join the integral outlets to heater tubes. Expensive nozzling-in and reinforcing operations are eliminated.**

**Ladish 90° Reducing Heater-Elbows and 45° Side Outlet Elbows used in combination with Ladish Seamless Multiple Outlet Fittings further cut installation costs . . . improve both design and flow efficiency.**

**These fittings are manufactured in a wide range of sizes and material specifications to the same rigid metallurgical and manufacturing standards which distinguish Ladish Controlled Quality Fittings.**




**1** Ladish streamline design simplifies installation, improves flow efficiency and assures ample expansion allowance between coil sections.

**2** Obsolete miter joint construction leaves insufficient space between coil sections, complicates installation, restricts expansion.

THE COMPLETE *Controlled Quality* FITTINGS LINE

**LADISH CO.**

CUDAHY, WISCONSIN
MILWAUKEE SUBURB

District Offices: New York • Buffalo • Pittsburgh • Philadelphia • Cleveland
Chicago • St. Paul • St. Louis • Atlanta • Houston • Odessa • Tulsa • Denver
Los Angeles • San Francisco • Seattle • Havana • Mexico City • Brantford, Ont.

**LADISH CO.**
**Cudahy, Wisconsin**

**We're interested . . . have Ladish representative call to discuss our application.**

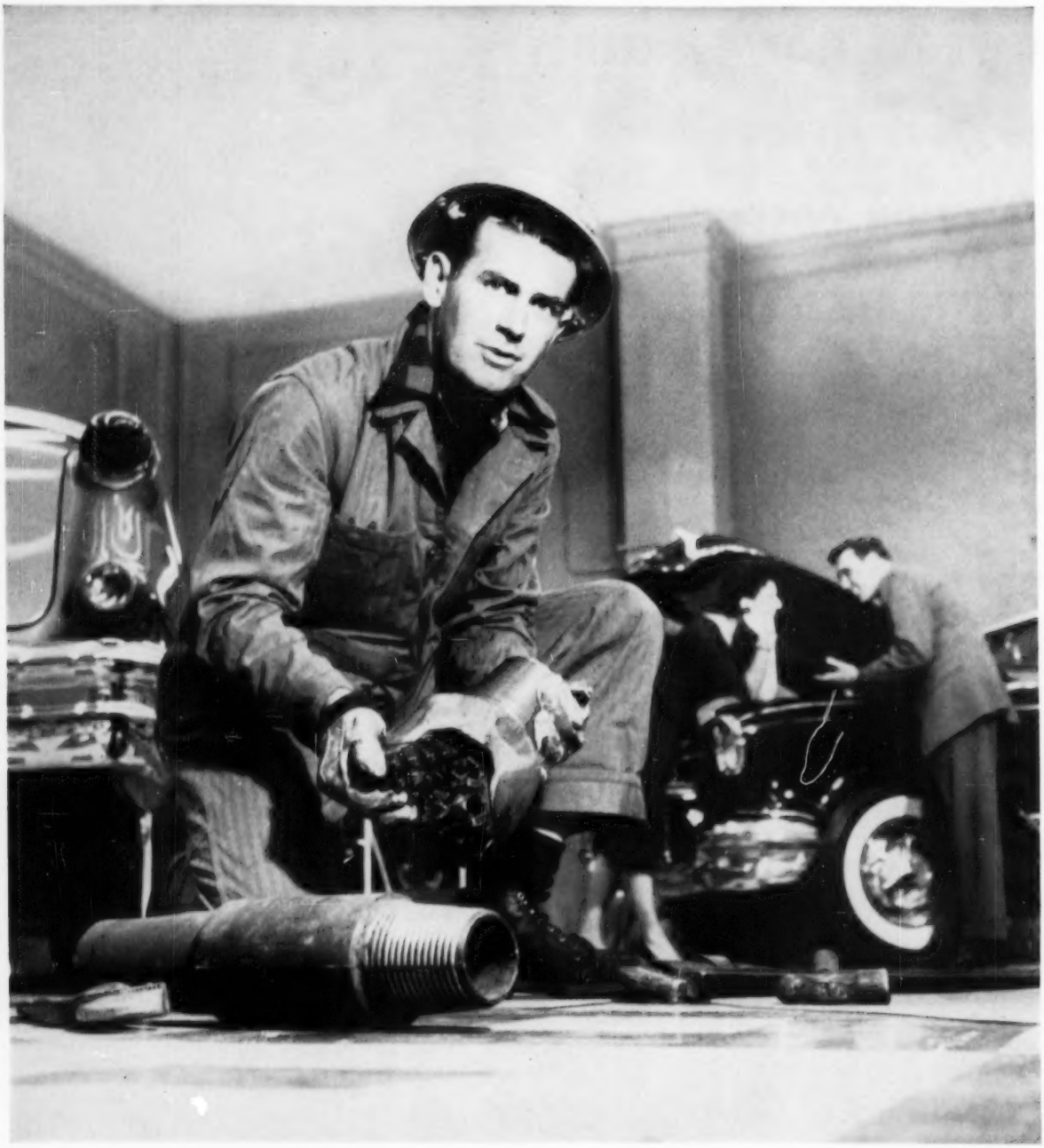
Name _____ Title _____

Company _____

Street _____

City _____ State _____

PR

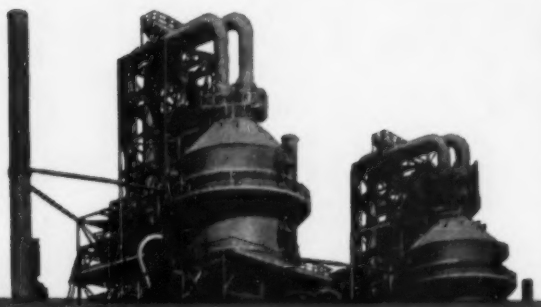


**All oilmen make this big sale possible!** Americans bought 7,169,908 new cars last year, filled 'em up with gasoline and oil and set out for fun or business. The ready availability of gas and oil helps close every car sale, keeps the auto industry moving. In fact, we oilmen—from drillers to pipeline men—help keep millions working at everything from agriculture to zoology. When you hear someone who doesn't know the facts criticize our industry, speak up. Tell how oil helps keep our strong economy rolling in high gear. Be proud you're an oilman. And tell the world! **SHELL OIL COMPANY**

SHELL

There is a specific A. P. Green Castable for every refractory application in the Petroleum Field. Methods of installation, including troweling, pouring, and "gun" application vary with the particular characteristics of the job. Each A. P. Green castable refractory is specifically designed to provide the required properties of insulation, strength, abrasion resistance and refractoriness for high efficiency operation.

*For detailed information and recommendations write the Engineering Department of the A. P. Green Fire Brick Company . . . or call your local A. P. Green distributor.*



**KAST-SET**
A. P. Green KAST-SET is a rapid setting, high strength refractory castable. Mixed with water, it takes on a hydraulic bond without the application of heat. KAST-SET will not shrink, has excellent resistance to abrasion, and is ideally suited for monolithic linings. It may be used at temperatures up to 2700°F.

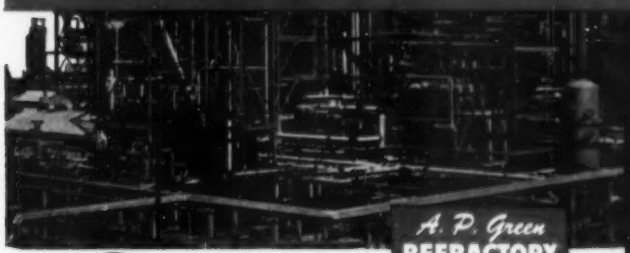
**KAST-O-LITE**
A lightweight, insulating castable refractory recommended for temperatures up to 2500°F. It is used for complete monolithic linings in all types of oil stills and heaters, tar stills, air heaters, heat treating furnaces, flues and stacks, and for furnace hearth insulation.

**CASTABLE INSULATION NO. 20**
A hydraulic-setting castable for temperatures up to 2000°F. Recommended for complete monolithic linings and lightweight panel construction in oil stills and heaters.

**CASTABLE BLOCK MIX**
A hydraulic-setting castable insulation for temperatures up to 1600°F. CASTABLE BLOCK MIX combines the advantages of a castable material with low conductivity and light weight.

# A.P. GREEN

**HIGH QUALITY REFRACTORY AND INSULATING CASTABLES ASSURE HIGH EFFICIENCY OPERATION OF PETROLEUM EQUIPMENT**



Esso Standard Oil Company's fluid catalytic cracking units at the Baton Rouge Refinery where A. P. Green products are in use.

A. P. Green REFRACTORY PRODUCTS

**CASTABLES FOR GUN APPLICATION**

**SK-7 and KS-4**
were designed for use in combination to form composite linings in catalytic regenerators, reactors, and other petroleum equipment. Frequently a lining utilizing only SK-7 or KS-4 will fulfill the requirements of the job.

**SK-7**
Gun application of SK-7 produces a lightweight lining with excellent strength and insulating efficiency. Ideal lining for ducts, flues and breechings.

**KS-4**
This strong abrasion resistant castable can be gun applied with a minimum of rebound loss. Recommended for catalytic regenerator linings, stack linings, bubble towers, and duct linings exposed to abrasion or corrosion.

**A. P. GREEN FIRE BRICK COMPANY**
Mexico, Missouri, U. S. A.

**PLANTS:**
Mexico, Mo.—Woodbridge, N. J.—Sulphur Springs, Texas

**IN CANADA:**
A. P. Green Fire Brick Company, Ltd.—Toronto 15, Ontario

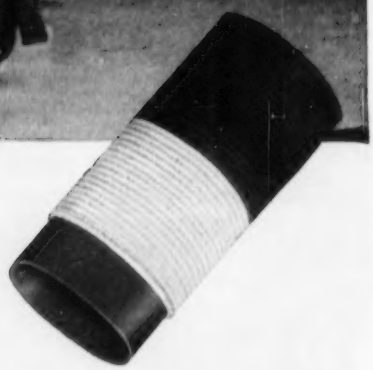
*DISTRIBUTORS IN THE PRINCIPAL CITIES OF THE WORLD*



For more data on advertised products, use Readers' Service Cards, last page.

Quaker

## Here's why this PETROCHEM fire hose is on guard throughout this D-X Sunray refinery



*Get acquainted with your Quaker-Quaker Pioneer distributor. You'll find him of real help—not only for your regular needs — but also in emergency situations requiring extra fast supply. Write for free brochure and name of your nearest distributor.*

This hose does *more* than fight fire. It fights off deterioration by oil and chemicals, stands up to abrasion, resists weather and functions safely under high pressure. Why? Because its oil-resistant Neoprene tube is enclosed in tough, wear-defying *Du Pont Dacron* impregnated with oil-proof Neoprene . . . this provides a tough, light, flexible hose, resistant to oil, both inside and out. Actually this hose is so strong that it can take pressures up to 500 lbs. and temperatures up to 300°F. . . . and so flexible that you can actually knot it. Easy to store, too! Either coiled or folded it takes little space.

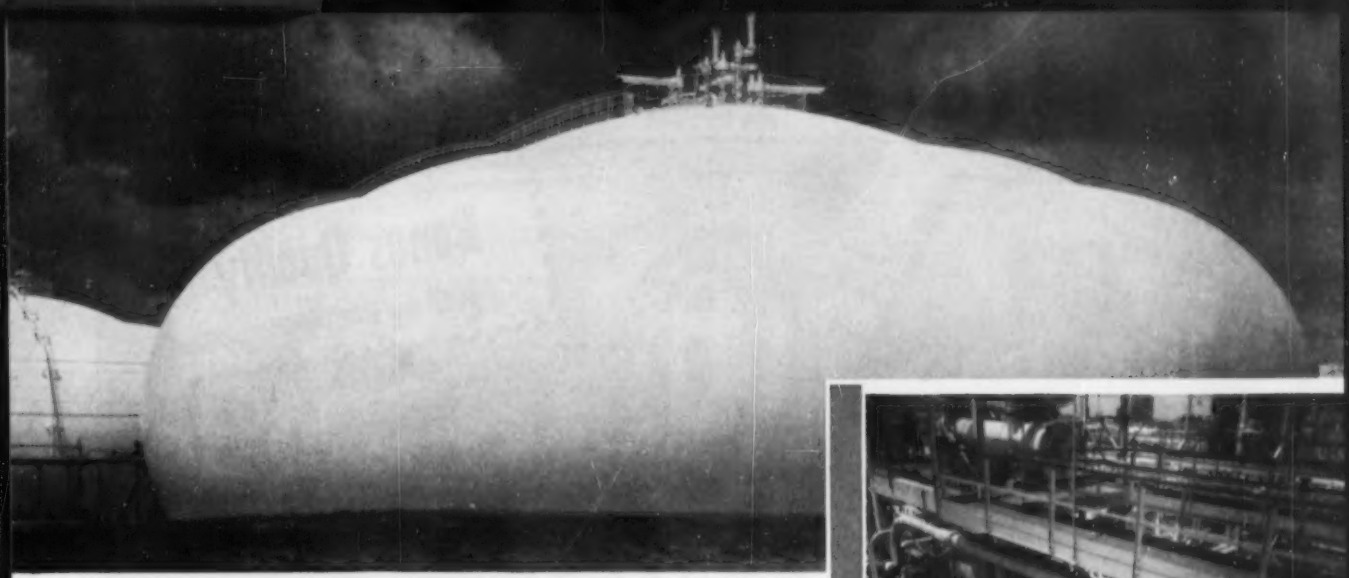
These are some of the reasons why D-X Sunray's Oklahoma refinery has this hose . . . the first made for oil and chemical industries, at all fire stations . . . and why it will pay you to consider it in your safety planning. Complete Quaker-Quaker Pioneer line includes hose for every purpose, belting, packing and moulded rubber for every use.

**H. K. PORTER COMPANY, INC.**

HKP

**QUAKER RUBBER DIVISION**
**Philadelphia 24, Pa.**

**QUAKER PIONEER RUBBER DIVISION**
**Pittsburg, Calif.**



One of the giant storage tanks at a large Gulf Coast Refinery. Many of the ladder treads are made of USS Multigrip Floor Plate.

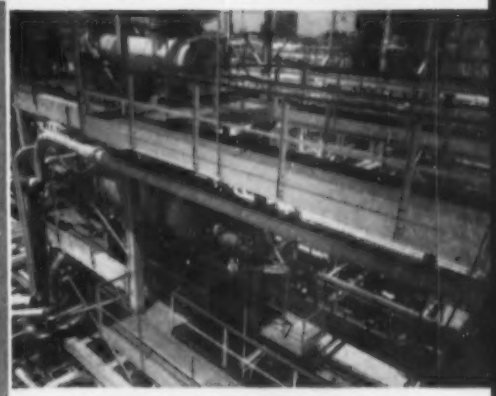
# Giant Refinery "safe-treads" walkways

## with USS Multigrip

Refineries along the Texas Gulf Coast are vast. Enormous cracking towers, refineries, catalysts and storage tanks process, store and ship huge quantities of petroleum products daily. Connecting most of the facilities are *elevated* walkways. The walking surfaces of a great majority of these runways consist of USS Multigrip Floor Plate.

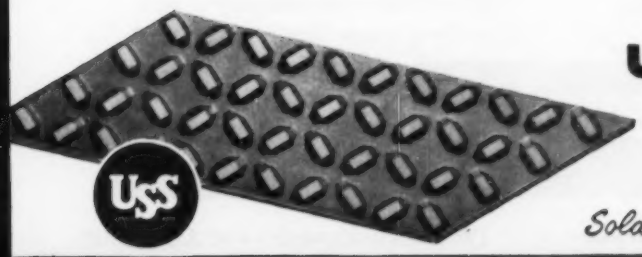
**Safe Footing**—Because they are used almost constantly no matter what the weather, it's extremely important that these walkways offer sure footing. Multigrip Floor Plate makes that possible because of its clean-edged, flat-topped risers. Every square foot has dozens of evenly spaced risers that give positive traction from any angle! Put Multigrip to hard use for years . . . and you'll still find no signs of chipping, cracking or splintering. It's a real blessing for maintenance budgets.

**Fits Your Plans**—Multigrip Floor Plate can be easily formed. Cutting or welding this floor plate is no problem, and it comes in large plates that help eliminate installation waste. For longest wear, for low maintenance, for the safety of your personnel . . . specify USS Multigrip Floor Plate.



A labyrinth of walkways—surfaced with Multigrip—makes it safe and convenient for personnel to move to all parts of this huge Refinery.

Multigrip's clean-edged, flat-topped safety risers give sure footing on these elevated walkways in any kind of weather. And the plates won't chip, crack or splinter.




**USS multigrip**

**FLOOR PLATE**

*Sold by leading distributors from coast to coast*

UNITED STATES STEEL

# Why Bucyrus-Erie Cranes are Tailored to Cut Your Maintenance Costs

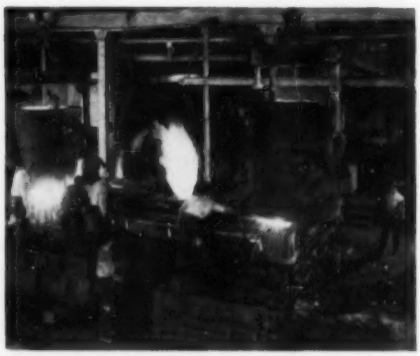
Strength to handle loads smoothly and easily . . . ability to inch those loads accurately into place . . . extra large area clutches and brakes that take hold uniformly with a smooth firm grip — these are some of the features of Bucyrus-Erie 22-B and 38-B cranes that enable them to handle refinery maintenance at lowest possible cost.

Their box-section booms are fabricated by the most modern welding processes with light steel chord angles strongly laced to stand up under the compression and swinging stresses applied in fast crane operation. An independent boom hoist enables the operator to change boom angle at any point in the cycle . . . permits accurate positioning of loads. The big clutches and brakes are instantly responsive, smooth in action, provide utmost load-handling ability. Special disc-type boosters on the 38-B drum clutches give the operator minute control.

Add to these the optional features of variable multiple-part boom suspension (pendant-type for 22-B; mast and pendant-type for 38-B) for obtaining slower boom hoisting and lowering and greater accuracy of control, independent propel and third drum equipment for the 38-B, and you'll see why it will pay to have your plant Bucyrus-Erie equipped. Crane capacities (75% rating): 23,700 lbs. for the 22-B with 35-ft. boom at 12-ft. radius (27,000 lbs. for Heavy Duty 22-B); 49,000 lbs. for the 38-B with 45-ft. boom at 15-ft. radius. Larger capacity crawler cranes and 15- and 25-ton Transit Cranes also available. 314E56

BUCYRUS ERIE

South Milwaukee, Wisconsin

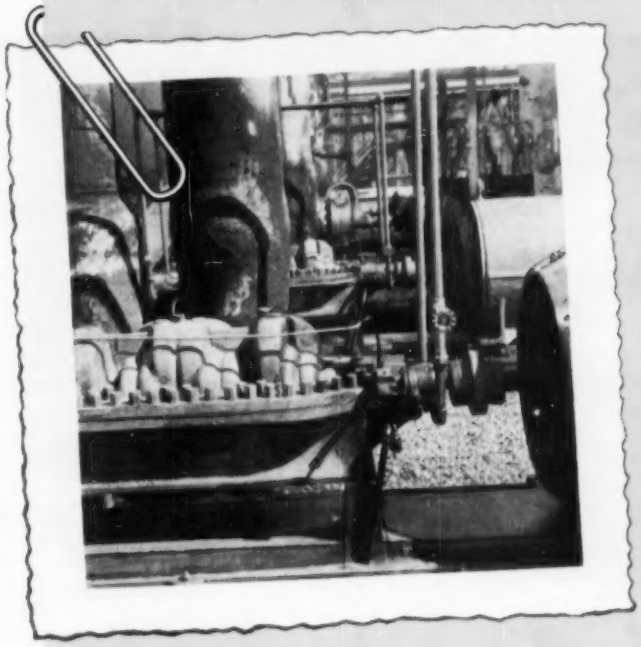


**Bonus Quality** Castings used in Bucyrus-Erie machines are produced in the company's own foundries where careful laboratory supervision holds them to the highest standards. Workmen are shown here pouring steel castings at the South Milwaukee Plant.

## BJ FIELD ENGINEERS' REPORT

Subject: Texas Gas Corp. installation

# BJ MECHANICAL SEALS BOOST OLD PUMPS' OUTPUT 124 GPM . . . ELIMINATE NEED FOR NEW PUMP INVESTMENT!



Expansion of the Texas Gas Corporation's Winnie, Texas refinery created a need for 120 gpm more output than the existing high pressure charge pumps were delivering. Two solutions were considered: (1). add another pump of the same size as the pumps already in operation; or (2). purchase a large single-capacity pump to replace existing pumps.

Working with Texas Gas engineers, Byron Jackson suggested a third solution: install BJ Mechanical Seals on the existing pumps. This eliminated the use of packing and throttle bushings and stopped the extreme leakage loss occuring at these points.

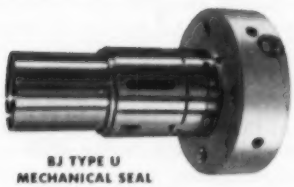
BJ Type U Mechanical Seals were installed on one of the pumps. Tests showed the flow rate was increased 62 gpm. The company immediately installed seals on their second charge pump. The new combined output of the mechanical-seal-equipped pumps was increased 124 gpm - more than sufficient to meet the expanded requirements.

In addition to this tremendous increase in pumping efficiency, other big benefits were realized: elimination of repacking expense and downtime losses; helpful savings in cooling water and piping; and a safer, cleaner working area around the pumps where formerly a "swamp" of leakage occurred.

Whatever your pumping requirements, it will pay you to investigate now the money-saving advantages of BJ Mechanical Seals. Call your local Byron Jackson office or write . . .

## 90% Saving on Piping!

After BJ Mechanical Seals were installed, approximately 90% of the piping was removed from the pumps. This maze of piping with packing had previously been necessary for cooling the stuffingboxes and for recirculating the high pressure leakage from the throttle bushings. Now there are only two lines used for handling cooling water to the bearing boxes and a 1¼" line running from seal cover to seal cover.



BJ TYPE U MECHANICAL SEAL

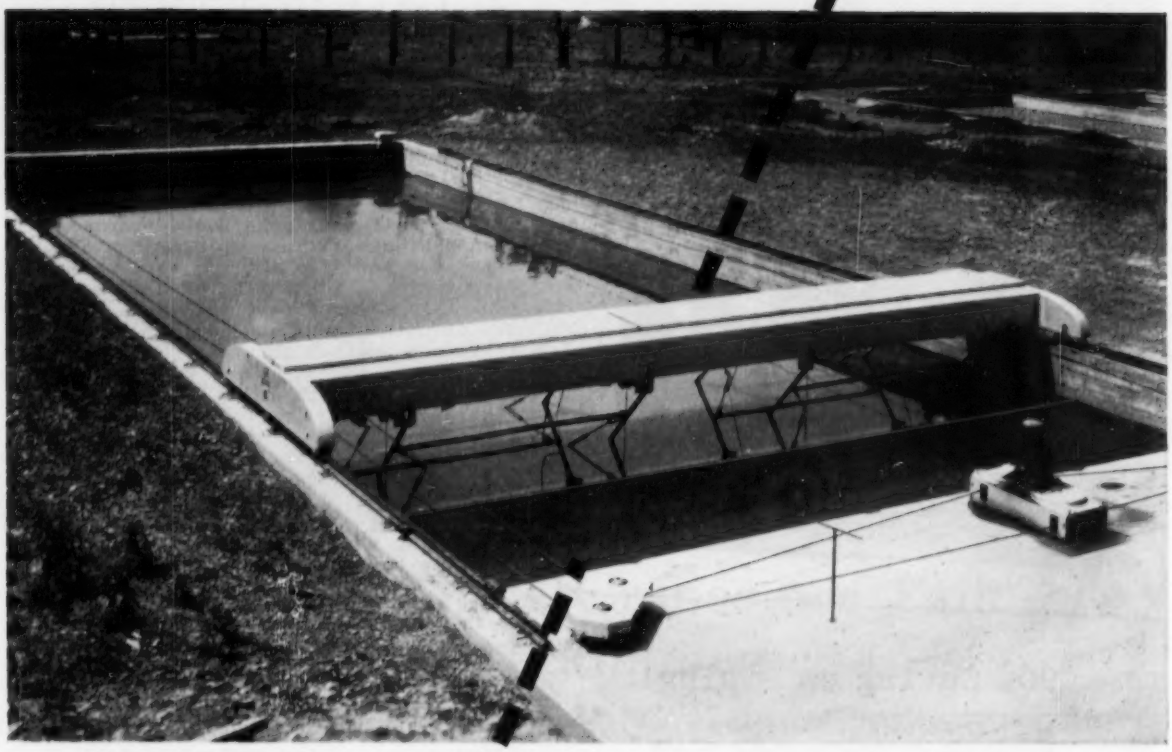
**BYRON JACKSON PUMPS**
INCORPORATED

A Subsidiary of Borg-Warner Corporation
P. O. BOX 2017A, TERMINAL ANNEX • LOS ANGELES 54, CALIFORNIA



For more data on advertised products, use Readers' Service Cards, last page.

# "POSITIVE OIL REMOVAL IN REFINERY WASTE TREATMENT"



*...with the* **Dorrco Monorake** *– the modern and economical method of cleaning oil-water separators*

**Positive and Complete Oil Removal** . . . Oil is positively and completely removed by skimmers after each cycle.

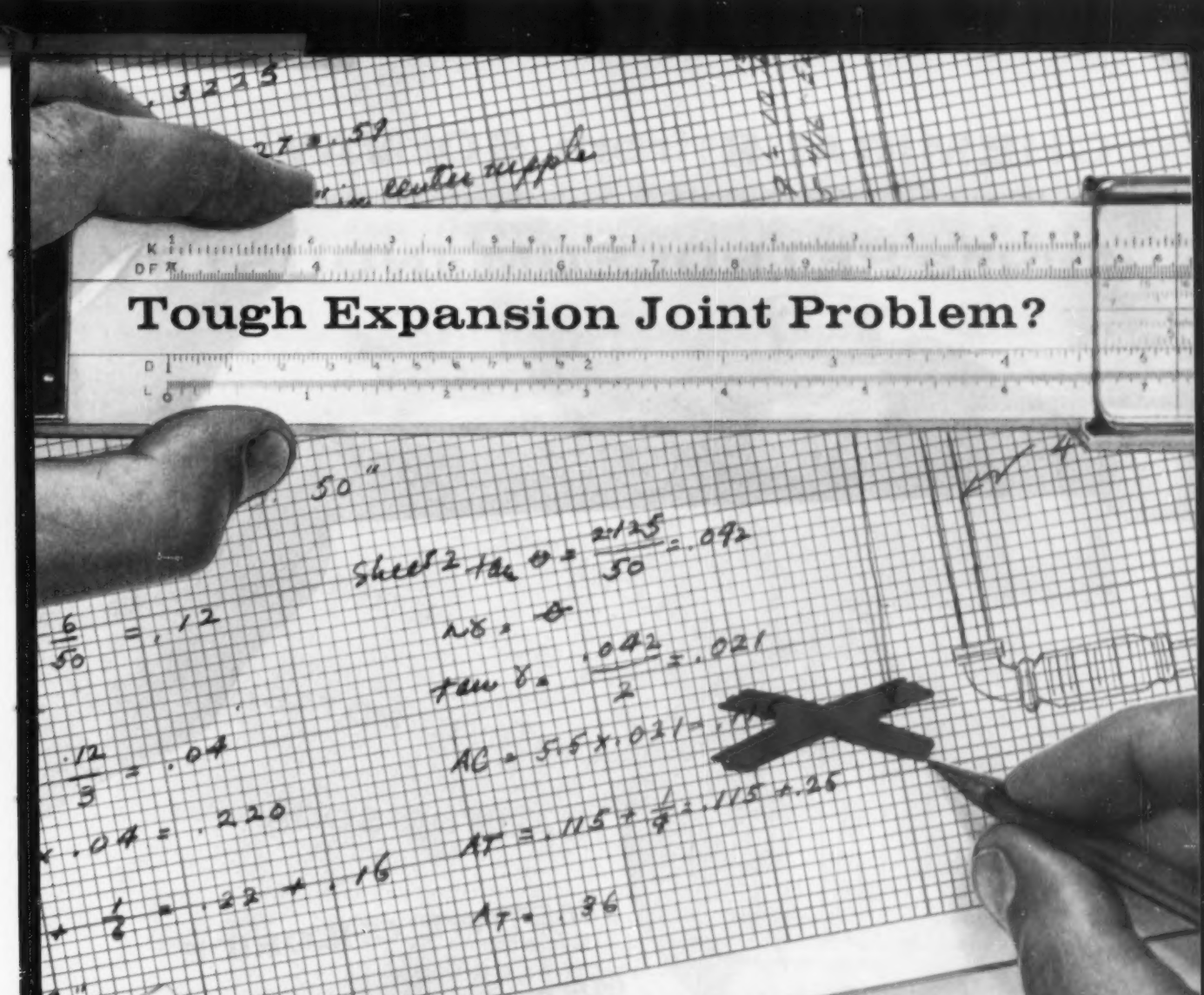
**Long Life — Minimum Maintenance** . . . a simple, rugged unit with accessibility of operating parts provides ease of adjustment and minimum maintenance.

**Wide Range of Sizes** . . . Monorake Units are available in widths ranging from 10 to 110 ft.

**Versatile** . . . The oil trough and sludge hopper can be installed at either the influent or the effluent end. Placement of oil trough at same end as sludge hopper provides for convenient testing and simplified operation.

For a more complete picture on the advantages and operation of the Dorrco Monorake, write for Bulletin No. 6001 — just off the press. No obligation, of course.

DORR-OLIVER
INCORPORATED
WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT
STAMFORD • CONNECTICUT • U.S.A.




## Put the Badger Man on the Spot!

Complex expansion joint problems are *best* analyzed at only one place: your office or plant site. It's there alone — where the figuring is going on — that *all* essential data about your proposed installation is available.

And it's there — *on the spot* — that the Badger Man can assist you. Because 1. he is a trained engineer; 2. he brings to your problem the background of the world's most experienced manufacturer of expansion joints.*

Next time you are confronted with a complicated piping layout, severe operating conditions, unusual size and shape requirements — *any* complex expansion joint problem — put the Badger Man on the spot! His services are as close as your telephone.

*COMING SOON — Badger Service-Rated Expansion Joints. Incorporate revolutionary new features developed during three years of intensive research and testing. Watch for this important announcement.*

* Badger has been solving tough expansion joint problems for 50 years — a record unmatched by any other firm.

BMC

**BADGER EXPANSION JOINTS**

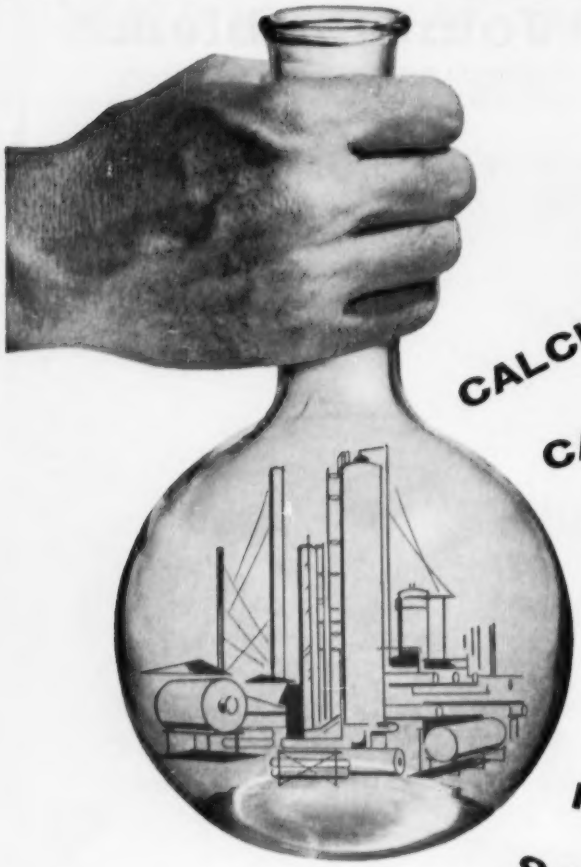
**BADGER MANUFACTURING COMPANY**

230 Bent Street, Cambridge 41, Massachusetts • 60 East 42nd Street, New York 17, New York

*Representatives in principal cities*

# CHEMICALS from SOLVAY®

# for the PETROLEUM INDUSTRY



CALCIUM CHLORIDE

CARBON TETRACHLORIDE

CAUSTIC POTASH

CAUSTIC SODA

METHYL CHLORIDE

METHYLENE CHLORIDE

SODA ASH

SODIUM NITRITE

SOLVAY offers the petroleum industry the benefit of 75 years experience in the field of alkalies and related products. SOLVAY assures you of top quality, dependable delivery and close, personal service. Call on SOLVAY *first*. Write or phone the SOLVAY office nearest your plant.

AMERICA'S FIRST PRODUCER OF ALKALIES — SOLVAY — 75th YEAR 1881-1956

**SOLVAY PROCESS DIVISION**

ALLIED CHEMICAL & DYE CORPORATION

61 Broadway, New York 6, N. Y.

Allied Chemical

BRANCH SALES OFFICES:

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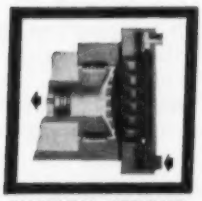
For more data on advertised products, use Readers' Service Cards, last page.

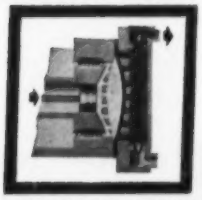
## CONTROLLED-VOLUME PUMPING with

# NO STUFFING BOX PROBLEMS!

The Pulsafeeder, in combining the good features of both piston and diaphragm pumps, provides an unusually dependable means of precision pumping. There is no stuffing box, hence the usual problems of maintenance and repacking associated with plunger-type metering pumps do not exist. The product being pumped is isolated from the pump's working parts by a hydraulically balanced diaphragm and is kept safe from contamination and leakage to atmosphere.



SUCTION STROKE



DISCHARGE STROKE

Positive displacement is achieved by a piston reciprocating within an accurately sized cylinder at an established stroke length, displacing an exact volume of hydraulic oil. By means of this oil, the piston moves the diaphragm alternately backward and forward. The displacement of this diaphragm travel takes in the liquid on the suction stroke of the piston and discharges a like amount of liquid on the discharge stroke of the piston.

**WRITE FOR BULLETIN 440** *with typical applications, flow charts, description and specifications of models of various capacities and constructions. Inquiry Data Sheet included from which we can make specific engineering recommendation for your processing requirement. Write Lapp Insulator Co., Inc., Process Equipment Division, 656 Wilson Street, Le Roy, N. Y.*

**Lapp**




For more data on advertised products, use Readers' Service Cards, last page.

SHOOT

POUR

TROWEL

**ADACAST extra strength refractory**

## ...SPECIALLY FOR PETRO-CHEM APPLICATIONS

. . . ADACAST Extra Strength is a castable that can be shot, poured or trowelled . . . *specially designed* for those applications where high strength and resistance to abrasion and fly ash erosion are of prime importance (where high temperature resistance is not so much a factor). For Oil Stills and Heaters . . . BOTFIELD Castables are manufactured in all grades . . . from high strength dense to extremely light weight . . . with high insulating value . . . for *every* purpose in the Refining and Chemical Processing Industries.

Write for the new BOTFIELD Refractory Castables bulletin # 27

Yellow pages of 'phone book have your nearest ADAMANT Distributor.

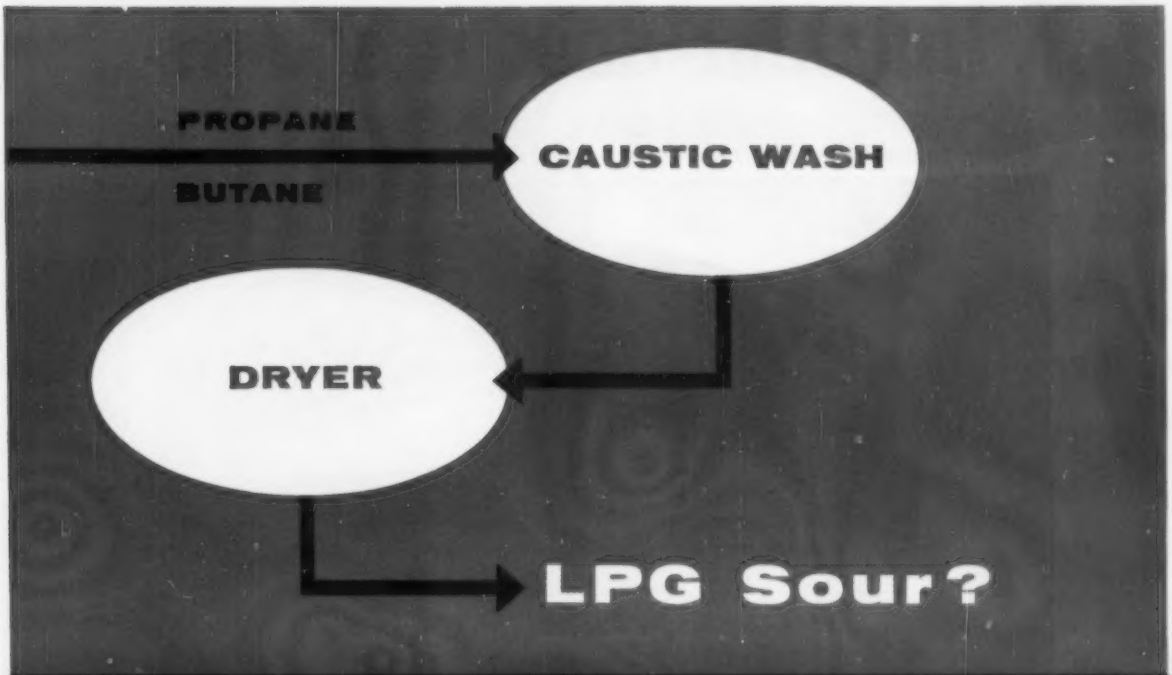
**Botfield**

FOUNDED 1907

**REFRACTORIES**

**ADAMANT and other ADA products**

**swanson and clymer sts.**
**philadelphia 47, penna.**




## Dry it sweet every time with DRIOCEL S

**DRIOCEL S IS NEW.** It is a low-cost, activated bauxite desiccant specifically developed to overcome souring of LPG products during the final drying step.

**DRIOCEL S PERFORMS A THREE-WAY TASK.**

1. It *does* a thorough job of drying the liquefied products.
2. It *does not* exhibit a souring reaction with sulfur compounds which originate in sour gases and crudes —escape the caustic wash—are entrained in the pre-dryer stream (which may deceptively test "sweet")—and then are decomposed in the dryer by ordinary desiccants to yield sour products.
3. Driocel S *does not* act as an acid polymerization catalyst toward heavy ends of the liquefied gases.

**LONG SERVICE LIFE**—Initial installations put on stream over two years ago are still operating.

**THE SPECIFIC PROPERTIES** of this new drying agent also suggest its use in the drying of chlorinated and fluorinated hydrocarbons.

Under the well-known brand name of Driocel, M & C offers a *complete* line of reliable desiccants for drying air, hydrogen, $CO_2$, hydrocarbon liquids and gases—further proof of our ability to solve many a tough processing problem with versatile sorptive minerals. The coupon will put us to work for you.

ATTAPULGUS **POROCEL PRODUCTS** *from*

**MINERALS & CHEMICALS CORPORATION OF AMERICA**
14 ESSEX TURNPIKE, MENLO PARK, N. J.

ALWAYS A BETTER WAY...

MINERALS & CHEMICALS CORPORATION OF AMERICA
14 Essex Turnpike, Menlo Park, N. J.

Please send me without obligation:

- ☐ Bulletin: "Bauxite As A Drying Agent"
- ☐ Generous sample of Driocel S

name_____ title_____

company_____

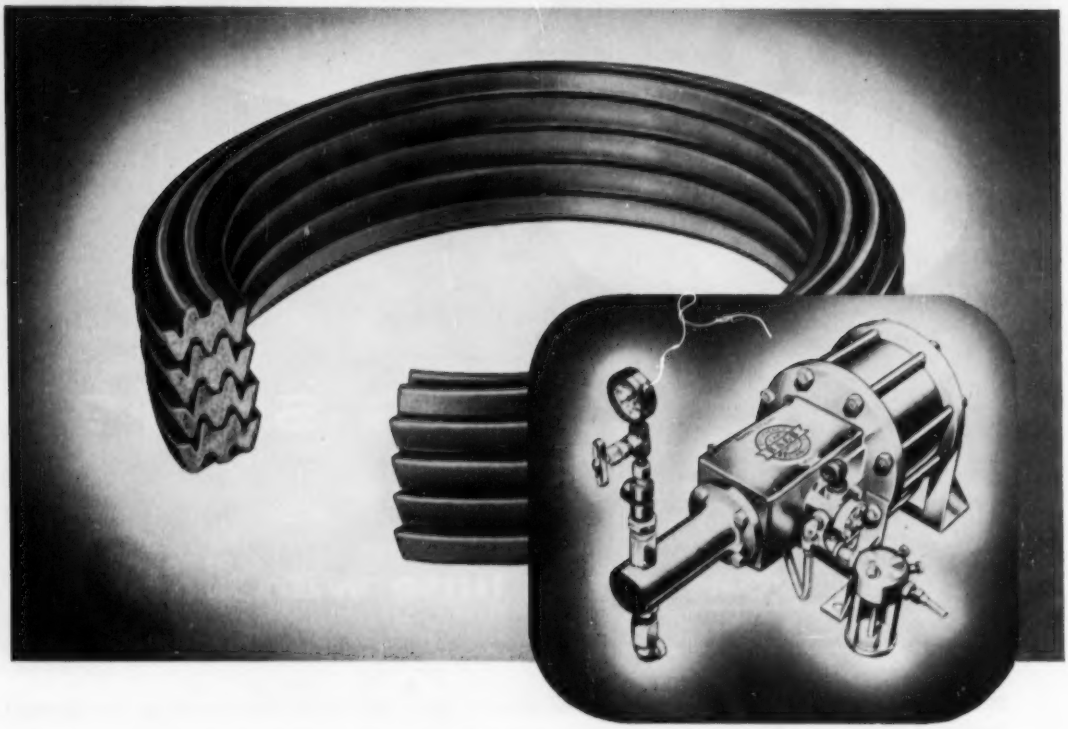
address_____

city_____ zone____ state_____



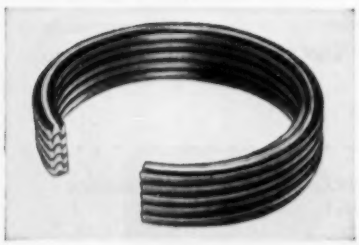
For more data on advertised products, use Readers' Service Cards, last page.

# J-M Uneepac® does it again!



"Very satisfactory sealing service against wide variety of fluids and pressures up to 5,500 psi"

**says Black, Sivalls and Bryson, Inc. makers of BS&B Glycol Pump**



**Uneepac comes in two types.** Shown here is design for flange widths up to ½" which is used in BS&B Glycol Pump. Large illustration above shows design for flange widths over ½".

Chalk up another success story for Uneepac—Johns-Manville's automatic ring packing. In the BS&B Glycol Pump, fluids handled include triethylene glycol, diethylene glycol, gasoline, and various types of oils, alcohols and petroleum treating chemicals. Working pressures range from 125 psi to 5,500 psi with average operating pressures at 3,000 psi. Yet despite these rugged service conditions, Uneepac has delivered—in Black, Sivalls and Bryson's own words—"very satisfactory service."

Many other packing users have acclaimed J-M Uneepac for its long, trouble-free service. Each ring is a complete packing unit. Fewer rings are needed than ordinarily required and stuffing box size can be reduced to the minimum. Each ring centers itself automatically on the preceding ring to simplify installation. This exclusive design also permits fluid pressure to act upon each lip individually and protects lips from excessive gland pressure.

J-M Uneepac comes in a wide range of styles and sizes for many rod and plunger applications. For further information write Johns-Manville, Box 14, New York 16, N. Y. In Canada, Port Credit, Ontario.

**Johns-Manville PACKINGS, GASKETS and TEXTILES**

## Now...Local Availability on

# Titeflex

### Seal-Tight, Time-Saving

# Quick-Seal Couplings

Titeflex Couplings are *leakproof* at *all* operating pressures—the higher the pressure the tighter the seal! Couple or uncouple in ONE second... without the aid of tools. Straight-through or single or double check-valve types. Allow free flow of *any* viscous material. Sizes from ¼" to 12" diameter. Made from a variety of metals and alloys to suit innumerable industrial applications.

# Titeflex

## Flexible Metal Hose

—the ideal "conveying mate" for Titeflex Couplings. Withstands high temperature and pressure stresses. Impervious to vibration and corrosive action.

Both these time-tested products are available for immediate shipment from distributors' stocks in most areas. Otherwise write, wire or telephone direct.

**CALL YOUR LOCAL DISTRIBUTOR**

Consult the yellow pages of your telephone directory

**Your one source for both Hose and Couplings**

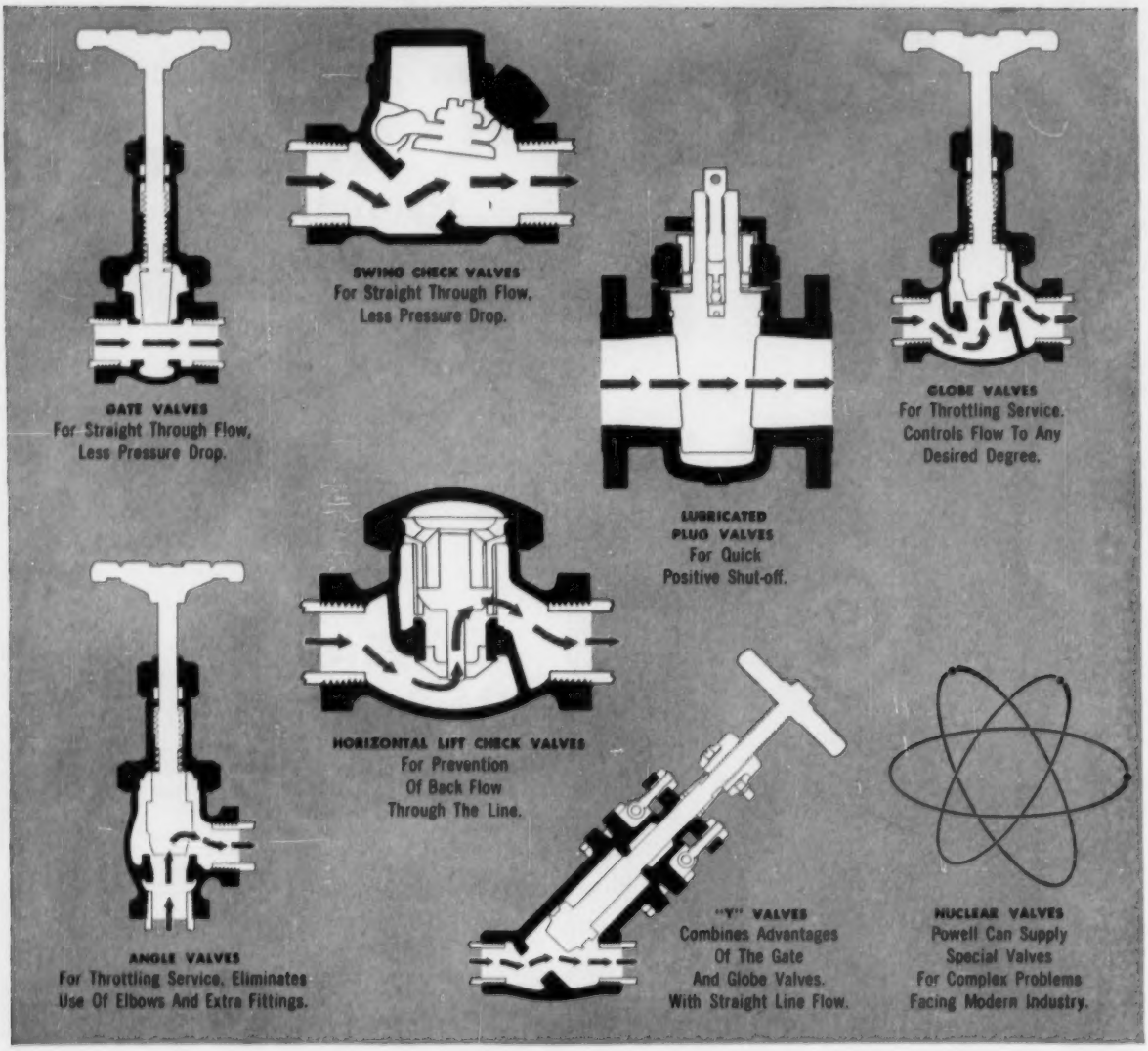
**Titeflex**

**TITEFLEX, INC., 600 HENDEE STREET, SPRINGFIELD 4, MASS.**



For more data on advertised products, use Readers' Service Cards, last page.

# POWELL
## for all valve needs




## for every flow control problem there is a right Valve

Powell can supply this right valve—*made right* of the right material*. Every part of every valve must pass rigid inspection. And as a final step in manufacture, every Powell Valve has *Performance Verified* through an *actual line test.*

As an aid in selecting the right valve, the basic valve designs are illustrated here. For complete information on the wide range of sizes and materials available in each type of the basic valves illustrated above, consult your Powell Valve distributor. If none is located near you—or if you have a special flow control problem—write direct to The Wm. Powell Company, Cincinnati 22, Ohio.

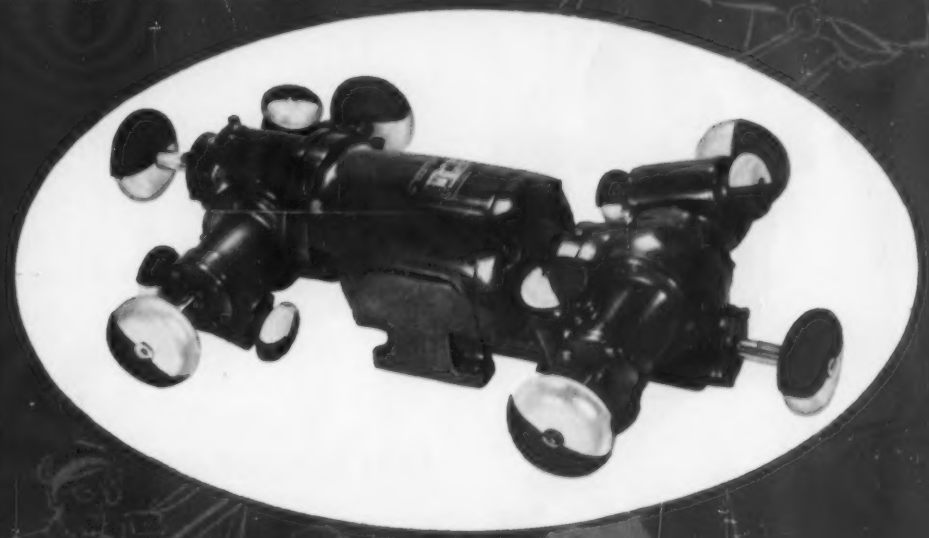
PERFORMANCE
PV
VERIFIED

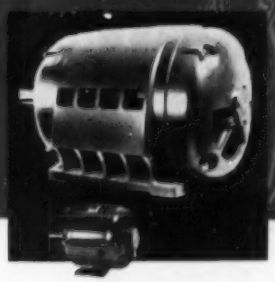
**The Wm. Powell Company, Cincinnati 22, Ohio . . . 110th YEAR**

# POWELL VALVES

*BRONZE, IRON, STEEL AND CORROSION RESISTANT VALVES.

# Why not build the cart before the horses?





Just tell us here at Master what you want in power drives—and get the utmost in flexibility, compactness and performance. It probably won't be as complicated as the multi-shaft Gearmotor illustrated here, with 14 shafts turning at diverse speeds. But, regardless of what you need, Master can supply the right combination of horsepower, shaft speed and mounting features with whatever Master components are required—all combined in one compact efficient unit. Just ask for information.

**Motor Ratings**. ⅛ to 400 H.P. All phases, voltages and frequencies.

**Motor Types**... Squirrel cage, slip ring, synchronous, repulsion-start induction, capacitor, direct current.

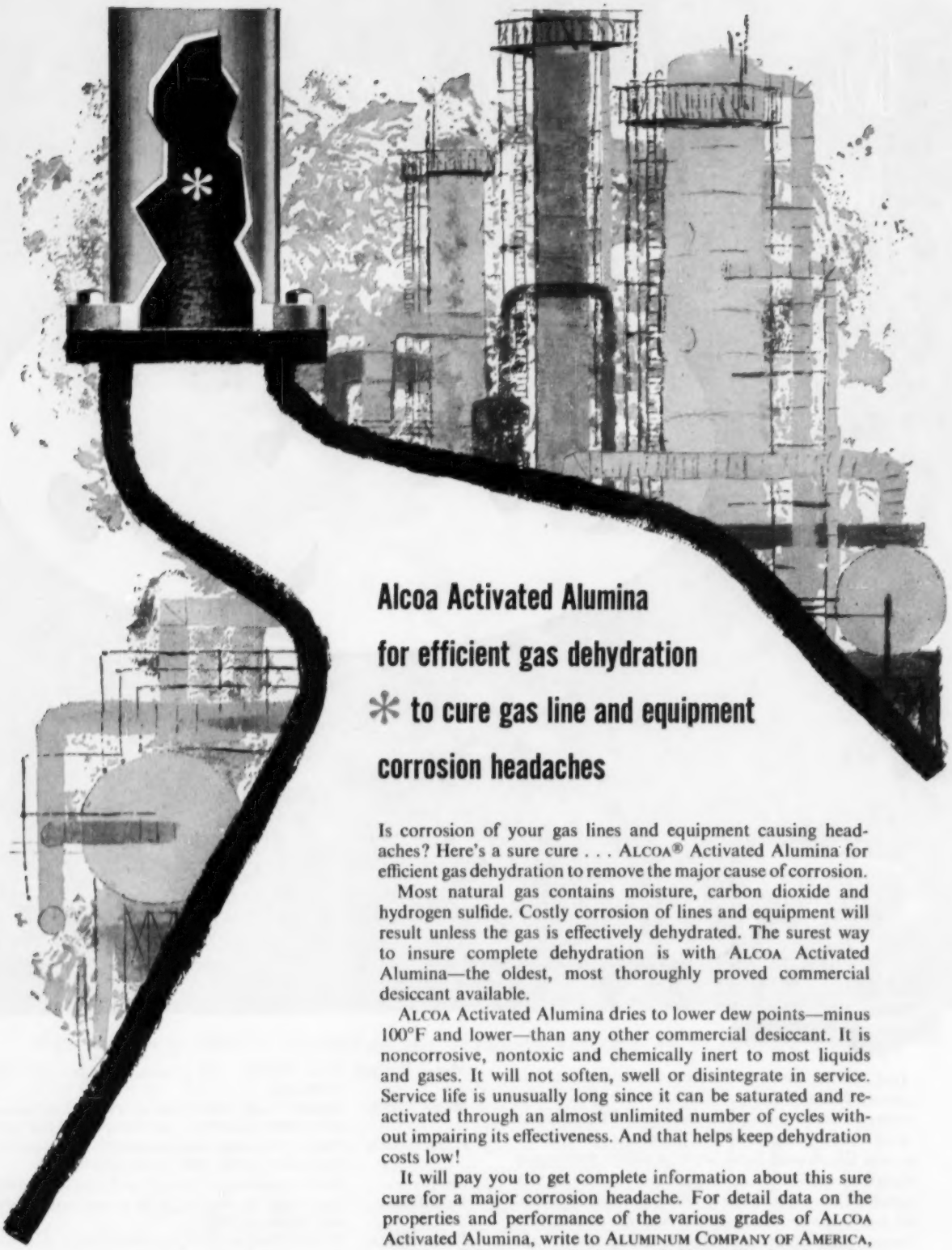
**Construction** .. Open, enclosed, splash-proof, fan-cooled, explosion-proof, special purpose.

**Speeds**..... Single-speed, multi-speed, and variable speed.

**Installation**.... Horizontal or vertical, with or without flanges and other features.

**Power Drive Features**..... Electric brakes (2 types)—5 types of gear reduction up to 432 to 1 ratio. Mechanical and electronic variable speed units—fluid drives—every type of mounting.

THE MASTER ELECTRIC COMPANY, Dayton 1, Ohio



## Alcoa Activated Alumina for efficient gas dehydration * to cure gas line and equipment corrosion headaches

Is corrosion of your gas lines and equipment causing headaches? Here's a sure cure . . . ALCOA® Activated Alumina for efficient gas dehydration to remove the major cause of corrosion.

Most natural gas contains moisture, carbon dioxide and hydrogen sulfide. Costly corrosion of lines and equipment will result unless the gas is effectively dehydrated. The surest way to insure complete dehydration is with ALCOA Activated Alumina—the oldest, most thoroughly proved commercial desiccant available.

ALCOA Activated Alumina dries to lower dew points—minus 100°F and lower—than any other commercial desiccant. It is noncorrosive, nontoxic and chemically inert to most liquids and gases. It will not soften, swell or disintegrate in service. Service life is unusually long since it can be saturated and reactivated through an almost unlimited number of cycles without impairing its effectiveness. And that helps keep dehydration costs low!

It will pay you to get complete information about this sure cure for a major corrosion headache. For detail data on the properties and performance of the various grades of ALCOA Activated Alumina, write to ALUMINUM COMPANY OF AMERICA, CHEMICALS DIVISION, 717-M Alcoa Building, Pittsburgh 19, Pa.

ALCOA CHEMICALS

THE ALCOA HOUR
TELEVISION'S FINEST LIVE DRAMA
ALTERNATE SUNDAY EVENINGS



For more data on advertised products, use Readers' Service Cards, last page.

## PETROLEOS MEXICANOS

# *Gas Processing Plant*

## REYNOSA, MEXICO

Below the Rio Grande, near Reynosa, in Tamaulipas, Mexico, Petroleos Mexicanos has recently completed this major gas processing project designed to process 300 million cubic feet of natural gas daily gathered from numerous fields within an area of about 400 square miles. About 8,000 barrels per day of fractionated products, including propane, butanes, motor fuel, naphtha and kerosene will be produced.

Engineering design and procurement of equipment was entrusted to Hudson, and the satisfaction of our client is attested by a current contract for a similar but even larger project for Petroleos Mexicanos on the Isthmus of Tehuantepec.

DESIGNERS AND CONSTRUCTORS OF
OIL AND GAS PROCESSING PLANTS

**HUDSON**
**ENGINEERING CORPORATION**

FAIRVIEW STATION • HOUSTON, TEXAS

# Newalls

## OFFER COMPLETE TECHNICAL SERVICE

NEWALLS are constantly expanding the scope of their technical service. Founded on 50 years of success in industrial insulation on land and sea they provide expert guidance on refinery insulation all over the world.

Newalls cover much more than the supply of first-class insulating materials. From plant conception to installation, and afterwards, Newalls offer a complete service on insulation problems. Our technical staff are ready to handle the specifications and estimation work for any type of plant, large or small, and provide skilled supervision on site.

Calling in our technical service ensures optimum performance.

Newalls insulation materials are in service on the following refineries:

**AUSTRALIA**
Altona
Kurnell
Kwinana

**BELGIUM**
Albatros Extensions, Antwerp,
C.B.P. (Compagnie Belge de Petroles)
Esso, Antwerp,
Petrofina, Antwerp

**BRAZIL**
Cubatao

**FRANCE**
Berre
Donges
Du Nord (Dunkirk)
Gonfreville
Lavera
Petite Couronne
Port Jerome

**INDIA**
Stanvac, Bombay

**MIDDLE EAST**
Abadan
Aden
Bahrain
Haifa
Kuwait
Ras Tanura

**VENEZUELA**
Amuay
Cardon

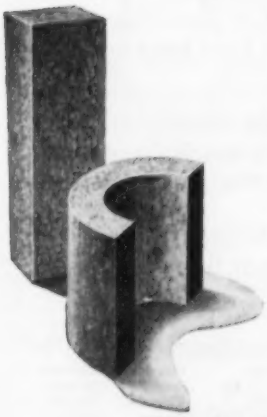
Newalls

## TECHNICAL ADVISORY SERVICE

NEWALLS INSULATION CO. LTD.,
WASHINGTON, CO. DURHAM, ENGLAND
*A member of the* TURNER & NEWALL ORGANISATION
*Agents and Vendors in most world markets*

# Insulation pure and simple

To begin with CAPOSITE needs no undercoat for protection—even against 1000°F. What is more the CAPOSITE blocks and pipe sections can be applied to cold surfaces, with absolutely no mess! This saves you weeks of time, pounds of money. CAPOSITE is the thermal insulation material with not only the highest efficiency but also with the lowest annual charge.*



**CAPOSITE** REGD
*Amosite Asbestos Blocks and Pipe Sections*

** annual heat loss value plus financial depreciation*

**THE CAPE ASBESTOS COMPANY LTD** • 114 & 116 Park Street, London, W.1 • *GROsvenor 6022*
*Canadian Enquiries: CAPE ASBESTOS (CANADA) LTD., 200 Bloor Street East, Toronto, Ontario*
*United States Enquiries: NORTH AMERICAN ASBESTOS CORP., Board of Trade Building, Chicago 4, Illinois*


For more data on advertised products, use Readers' Service Cards, last page.

# ON THE NOSE

## PRECISE ALLOY MIX GIVES *extra life* TO CHASE® ANTIMONIAL ADMIRALTY HEAT EXCHANGER TUBES

Strange that such a simple little thing as weighing could add years of life to a heat exchanger tube. Yet this careful weighing, plus extra care in manufacture, is why Chase Antimonial Admiralty Heat Exchanger Tubes *do* last longer!

Thanks to this weighing process, Chase Antimonial Admiralty Heat Exchanger Tubes contain *exactly* the right combination of metals to resist the ravages of dezincification. As a result, Chase Antimonial Admiralty Heat Exchanger Tubes mean lower operating costs, fewer breakdowns, more time between tube replacements!

Next time you plan a new installation, or replace heat exchanger tubes, install Chase Antimonial Admiralty. Enjoy extra years of service!

**CHASE WAREHOUSE STOCKS:** Beaumont,* Houston,* Los Angeles, New Orleans, Tulsa**

*Handled by Standard Brass & Mfg. Co. **Handled by Vinson Supply Co.

Chase®

**BRASS & COPPER CO.**

**WATERBURY 20, CONNECTICUT • SUBSIDIARY OF KENNECOTT COPPER CORPORATION**

*The Nation's Headquarters for Brass, Copper & Stainless Steel*

| | | | | | |
|---|---|---|---|---|---|
| Atlanta | Chicago | Denver | Indianapolis | Minneapolis | Philadelphia |
| Baltimore | Cincinnati | Detroit | Kansas City, Mo. | Newark | Pittsburgh |
| Boston | Cleveland | Grand Rapids | Los Angeles | New Orleans | Providence |
| Charlotte | Dallas | Houston | Milwaukee | New York | Rochester |
| St. Louis | San Francisco | Seattle | Waterbury | | |

**Refractory Castables are SPECIALIZED**

# *Which are best to use in refinery units?*

Naturally, the type of refractory castable selected depends upon the specific service. B&W makes a line of specialized refractory castables which are being widely used in catalytic reformers and catalytic cracking units, as well as in furnaces, ducts and stacks. For easy reference, here are some typical applications together with the recommended B&W Refractory Castables:

| APPLICATION | DESIRABLE PROPERTIES | RECOMMENDED B&W CASTABLES |
|---|---|---|
| Linings of catalytic reformers | Extremely low iron content, extra high strength.<br>Extremely low iron content, plus good insulation.<br>Low iron content, high temperature use limit. | Kaocrete LI<br>Kaolite LI<br>Kaocast |
| Lining desulphurizers | Good workability | Kaocrete B |
| Transfer lines and regenerators of catalytic cracking units | Extra abrasion and erosion resistance. | Kaocrete D |
| Heads of reactors and regenerators | Plasticity, excellent workability. | Kaocrete B |
| Insulating furnace floors | Good insulation, light weight | Kaolite-20<br>Kaolite-22 |
| Tube sheets | Good insulation, light weight | Kaolite-20<br>Kaolite-22 |
| Burner blocks | High temperature use limit, refractoriness and spalling resistance. | Kaocast |
| Openings where doors and other points are subject to mechanical abuse | Extra abrasion and erosion resistance | Kaocrete D |
| Furnace doors | Good insulation, light weight | Kaolite-20<br>Kaolite-22 |
| Ducts and stacks | Good insulation, light weight | Kaolite-20 |

Bulletin R-35 contains additional information on B&W Refractory Castables. Send for your copy.

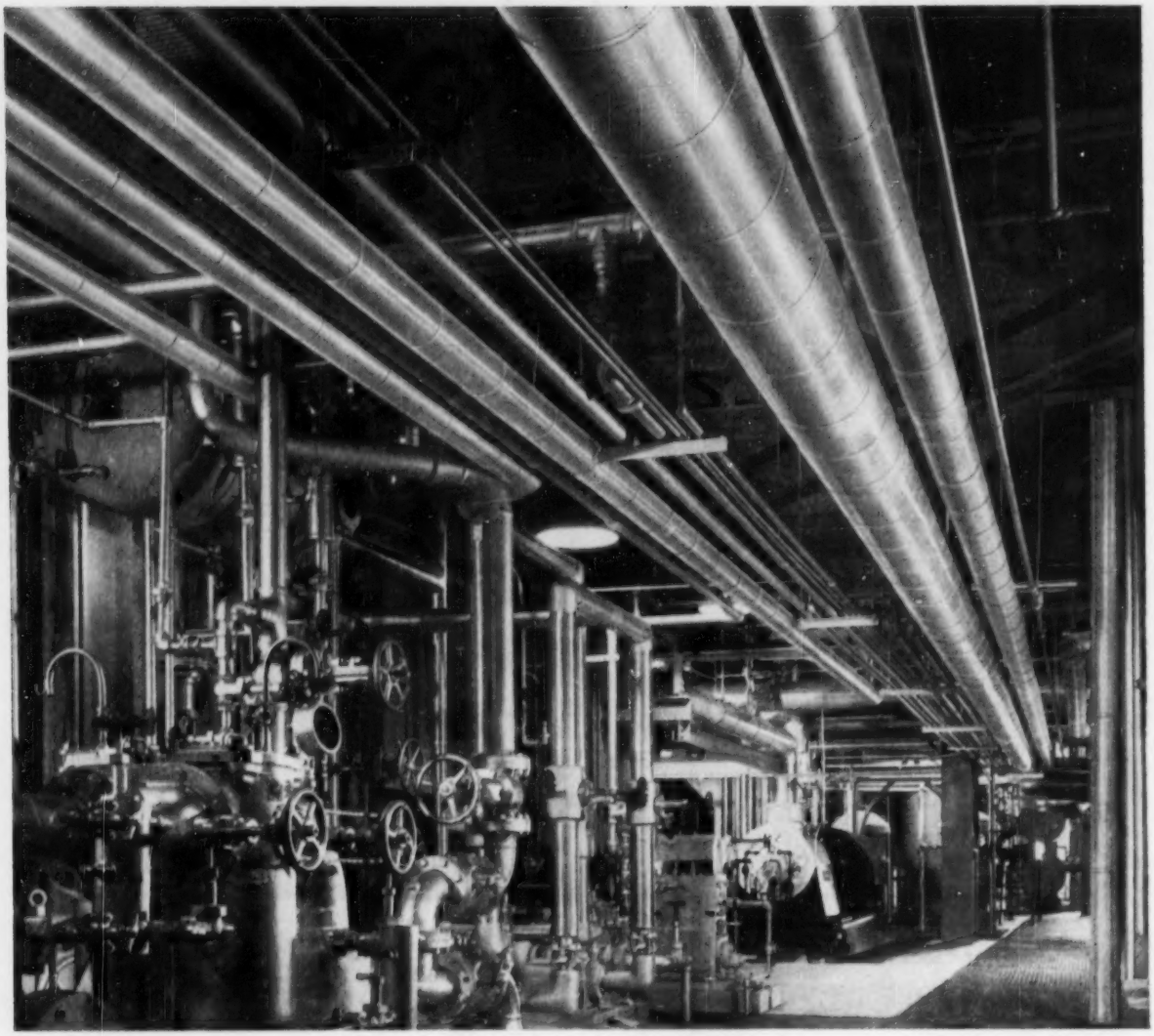
**B&W REFRACTORIES PRODUCTS:** B&W Allmul Firebrick • B&W 80 Firebrick • B&W Junior Firebrick • B&W Insulating Firebrick • B&W Refractory Castables, Plastics and Mortars • B&W Silicon Carbide

**BABCOCK & WILCOX**

THE BABCOCK & WILCOX CO.
REFRACTORIES DIVISION
GENERAL OFFICES: 161 EAST 42nd ST., NEW YORK 17, N.Y.
WORKS: AUGUSTA, GA.

## Kaiser Aluminum snap jackets give you

# A NEW, FASTER WAY TO



Now, with *snap jackets* made with Kaiser Aluminum, one man can install aluminum pipe jacketing quickly and economically.

An outstanding example of recent improvements in aluminum jacketing techniques, the *snap jacket* is a sheet of Kaiser Aluminum, roll-formed into a tubular shape and stiffened along one edge by an angular crimp. Rigid, but sufficiently flexible, the jacket can be quickly snapped into place around insulated pipe by only *one man* and assures a more durable, more weather-tight installation.

Because it is made with Kaiser Aluminum, the *snap jacket* gives you improved appearance and longer life at low cost.

For immediate assistance on any jacketing requirements, call the Kaiser Aluminum sales office listed in your phone directory. Process Industries Department, Kaiser Aluminum & Chemical Sales, Inc., *General Sales Office,* Palmolive Bldg., Chicago 11, Illinois; *Executive Office,* Kaiser Bldg., Oakland 12, California.

# INSTALL ALUMINUM JACKETING

**1. ONE MAN** can quickly position tubular *snap jacket* for installation.

**2. NEXT,** same man easily snaps *snap jacket* around pipe, places laps properly and bands the jacket to complete the job.

**3. TO SAVE** even more time, two men can work together . . . one man snaps jackets in place, follow-up man bands them.

For this new, faster way to install aluminum jacketing, Kaiser Aluminum alloy 5005-H16 is recommended. Other alloys may be used depending on the job, but it is desirable to use one alloy throughout.

**Recommended thicknesses of sheet aluminum:**

| | |
|---|---|
| **For insulation O.D. of 12.75" and under** | **0.020"** |
| **For insulation O.D. of 14" and larger** | **0.024"** |

**Kaiser Aluminum**

**materials for the process industries**

For *complete* information about aluminum jacketing with illustrated on-the-job techniques, send for the new 40-page *free* manual "Kaiser Aluminum Insulation Jacketing Materials And Methods."

**MAIL THIS COUPON TODAY!**

**KAISER ALUMINUM & CHEMICAL SALES, INC.,**
**Process Industries Department, Room 71211**
**1924 Broadway, Oakland 12, California**

Please send my copy of your new manual "Kaiser Aluminum Insulation Jacketing Materials And Methods." I understand there is no obligation.

NAME _____ TITLE _____

COMPANY _____ ADDRESS _____

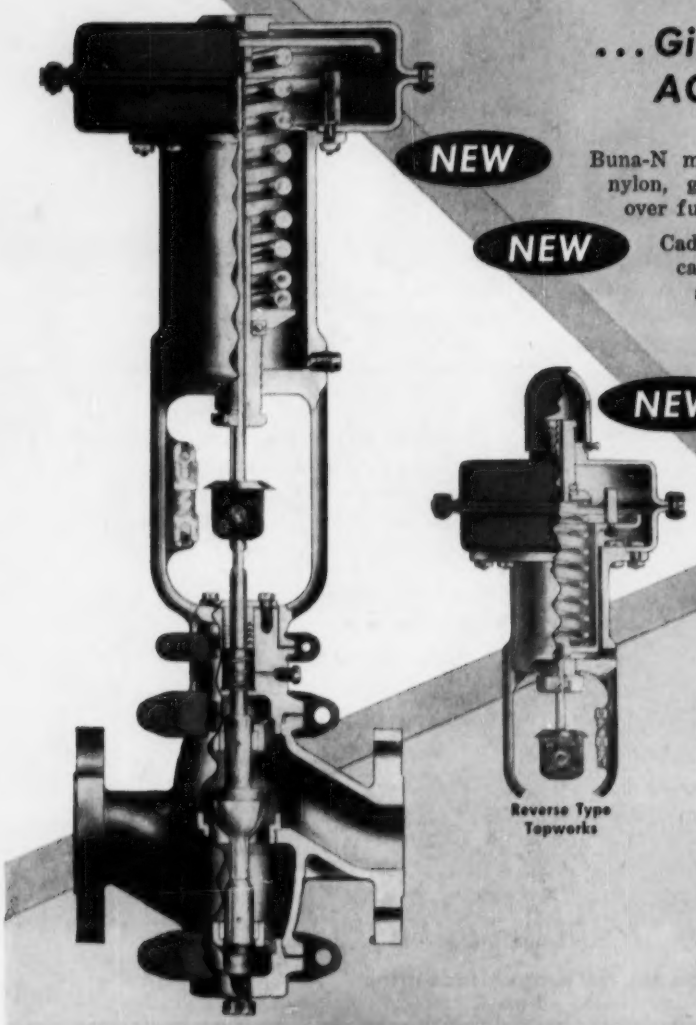
CITY _____ STATE _____



For more data on advertised products, use Readers' Service Cards, last page.

# New BS&B Super 70 series TOPWORKS

## ...Give FAST, ACCURATE Response!



Reverse Type Topworks

**NEW** Buna-N moulded diaphragm, reinforced with nylon, gives uniform cross sectional thrust over full valve travel.

**NEW** Cadmium plated pressed steel diaphragm cases give maximum strength and corrosion resistance with minimum weight. Special chromate treatment provides superior bonding agent for paint and added corrosion protection.

**NEW** Bolted clamp ring device integrates body and topworks assemblies into a single unit, and permits yoke to be oriented to any convenient position for observation and action.

**Four sizes of Super 70 Series Topworks** are available in both direct and reverse acting types. Both are interchangeable on single port, double port, or split body styles. A single spring, precision calibrated to plus or minus 2% of rating, provides accurate travel response to changes in diaphragm loading pressure. (Reverse type topworks uses recessed spring). Ductile iron yoke provides the rigidity of cast iron and the safety of steel. All units use split and bolted stem connector and adjustable travel scale plate.

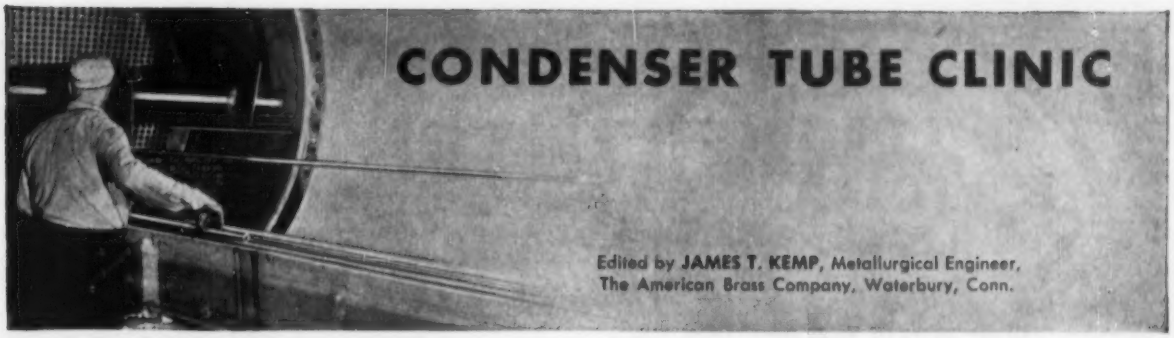
This advertisement highlights only features of the Super 70 Series Topworks. For information on the new valve bodies of the Super 70 Series line, ask for Catalog 70-11.

EFFICIENCY · OVER 60 YEARS · BS&B · RELIABILITY · ANOTHER EXAMPLE OF PRODUCT LEADERSHIP

**BLACK, SIVALLS & BRYSON, INC.**

Controls Division, Dept. 4-F12

7500 East 12th Street Kansas City 26, Missouri

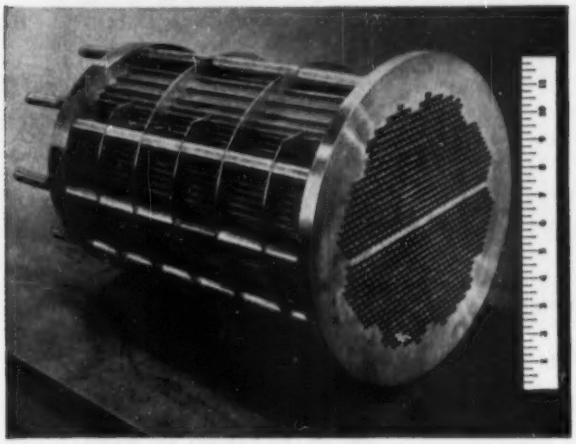


# CONDENSER TUBE CLINIC

Edited by **JAMES T. KEMP**, Metallurgical Engineer, The American Brass Company, Waterbury, Conn.

## 20" x ¼" O.D. Tubes need Same Care and Attention as large 60-foot Condenser Tubes

**The Tube Bundle** shown below is only 12 inches in diameter and 20 inches long. It is the heart of the compact, efficient lubricating-oil cooler built by the Andale Company, Lansdale, Pennsylvania.



In each bundle there are 946 tubes, each 20 inches long, ¼-inch O.D. by 0.035-inch wall thickness. They are of ANACONDA Phosphorized Arsenical Copper-108 for fresh-water duty or of ANACONDA Ambraloy-927 (Aluminum Brass), ANACONDA Cupro Nickel, 10%-755, or ANACONDA Cupro Nickel, 30%-702 for salt water. They are expanded in high-strength rolled ANACONDA Ambraloy-917 (Aluminum Bronze) tube sheets.

When the tubes are brass, the complete tube bundle is stress-relieved as an assembly at a temperature of 550 F.

These small tubes—cut to short lengths, with ends burnished, highly finished surfaces inside and out, close dimensional tolerances—are typical of The American Brass Company's product, although at the lower end of the schedule of sizes.

**The Same Precision** in control of alloy, dimensions, anneal or temper governs the manufacture of all ANACONDA Heat Exchanger Tubes in the plants of The American Brass Company—from these little oil-cooler tubes on up to the largest sizes used in sugar evaporators, and the long lengths needed in high-pressure feed-water heaters in steam power stations.

**Full Range.** ANACONDA Heat Exchanger and Condenser Tubes are made for all sizes and kinds of shell-and-tube, submerged, spray-tower, and finned-atmospheric heat transfer equipment—for operation at elevated temperatures in conformance with ASME standards for allowable stresses.

**Technical Assistance.** Our Technical Department is regularly helping manufacturers, electric companies, marine operators, petroleum and chemical companies to select the correct tube alloy for many types of condensers and heat exchangers. This service is available to you without obligation. Write: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Ltd., New Toronto, Ontario.

5681

**ANACONDA®**

**Tubes and Plates for Condensers and Heat Exchangers**

**PHYSICAL PROPERTIES OF ANACONDA CONDENSER TUBES***

| ALLOY | Tensile Strength, psi | Yield Strength at .5% Elongation Under Load, psi | Elongation in 2", % | Rockwell Hardness, B Scale | Density, Lb. per Cu. in. | Thermal Conductivity, B.T.U./Sq. Ft./ In./Hr./°F. at 68° F. | Average Coefficient of Linear Thermal Expansion per °F. (77-572 F.) |
|---|---|---|---|---|---|---|---|
| Arsenical Admiralty-439 | 52,000 | 22,000 | 60 | 6-45 | 0.308 | 768 | .0000112 |
| Ambraloy-927 | 60,000 | 27,000 | 55 | 35-65 | 0.301 | 696 | .0000108 |
| Ambraloy-901 | 60,000 | 30,000 | 60 | 30-60 | 0.295 | 552 | .0000099 |
| Cupro Nickel, 30%-702 | 55,000 | 22,000 | 50 | 30-60 | 0.323 | 204 | .0000090 |
| Cupro-Nickel, 10%-755 | | | | | | | |
| Light Annealed | 44,000 | 22,000 | 46 | 25 | 0.323 | 314 | .0000093 |
| Light Drawn | 60,000 | 57,000 | 15 | 68 | | | |
| Red Brass-24 | 42,000 | 15,000 | 50 | 0-30 | 0.316 | 1104 | .0000104 |
| Ambronze-421 | 46,000 | 20,000 | 55 | 0-30 | 0.316 | 830 | .0000102 |
| Phosphorized Arsenical Copper-108 | | | | | | | |
| Light Drawn | 40,000 | 35,000 | 20 | 20-50 | 0.323 | 1344 | .0000098 |
| Hard Drawn | 54,000 | 50,000 | 8 | 50-70 | | | |
| Phosphorized Copper-103 | | | | | | | |
| Light Drawn | 40,000 | 35,000 | 20 | 20-50 | 0.323 | 2364 | .0000098 |
| Hard Drawn | 54,000 | 50,000 | 8 | 50-70 | | | |

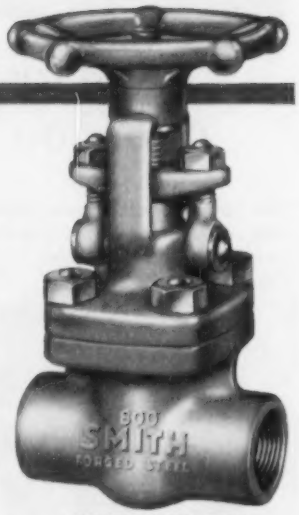
*Note: The above values are approximate and should not be used for specification purposes. *Light annealed except as noted.*



For more data on advertised products, use Readers' Service Cards, last page.

# Smith FORGED STEEL Valves

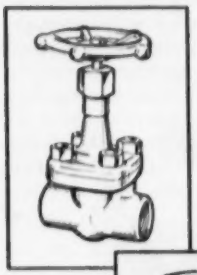
# They last longer... cut maintenance costs



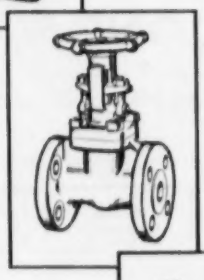

SMITH "FIGURE 800" O S & Y GATE VALVE

To Maintenance Engineers — the men who must keep a refinery "on stream" 24 hours a day, day in and day out, month after month. The installation of efficient, long-lasting, trouble-free equipment is of vital importance. That's why, among other things, they are looking for better all-purpose utility small steel valves that will stand up for long periods of time under ever-increasing pressures, temperatures and corrosion.

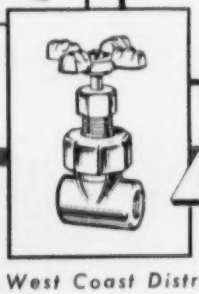
SMITH VALVES offer to maintenance men an easy solution to the small valve problem. They were designed especially for the Refinery and Petrochemical industries. A combination of special features, each tested and proved in actual service in these industries, makes them the finest in their class. "Balanced design", the best quality materials and precision workmanship combine to produce valves that give longer life in service.



INSIDE SCREW VALVES



FLANGED END GATE VALVES



NEEDLE GLOBE VALVES

## NOTE THESE SPECIAL FEATURES

- *Forged Steel body,* bonnet and gland guarantee maximum strength and highest factor of safety.
- *Bolted Bonnet-Flexitallic Gaskets* — insure a positive tight joint. These premium priced gaskets are generally re-usable.
- *Stem "375 Brinell"* — Rolled Threads — unique design — results in smooth positive operation and longer packing life.
- *"T-Head"* stem and gate connection has been engineered to insure balanced strength and positive operation.
- *Stainless Steel* eyebolts and nuts plus two-piece forged steel gland and Cr. 13 follower are always adjustable.
- *"Tear Drop"* designed gate, in combination with the accurately broached body guides, results in perfectly controlled operation in high pressure and temperature service.
- *"500 Brinell Gate"* — plus "diamond hard" chrome-faced seats — minimizes seizing, galling and abrasive wear.
- *Packing* — moulded asbestos, mica lubricated, wire reinforced reduces stem corrosion and electrolytic action.

**NEW ENGLAND VALVE Corporation**

**P. O. BOX 1047 • WORCESTER, MASSACHUSETTS**

*West Coast Distributors:* BETHLEHEM SUPPLY CO., LOS ANGELES, CALIFORNIA



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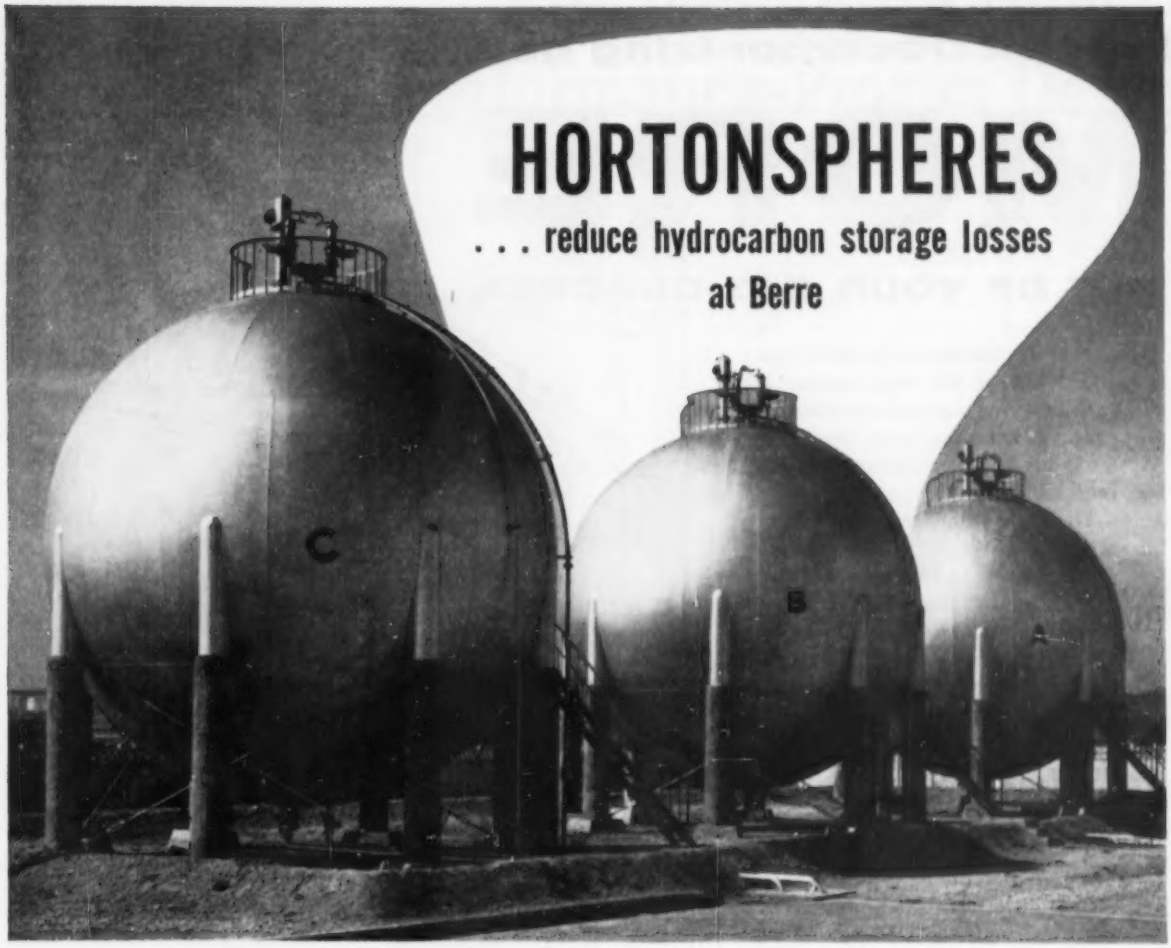


Three Hortonspheres®, structures designed and erected to withstand internal pressure, are reducing evaporation losses of volatile hydrocarbons stored at the Butagas plant in Berre, France. No vapor can escape from these Hortonspheres as long as the settings of the pressure relief valves are not exceeded.

Hortonspheres, available in capacities up to 30,000 bbls. and for pressures up to 217 lbs. per sq. in. in the smaller sizes, are used to store the more volatile grades of natural gasoline, butane, butane-propane mixture and refinery stocks. Complete information or quotations may be had by writing our nearest office.

CBI

**Chicago Bridge & Iron Company**

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## Solvent Decarbonizing gets

# MORE

## OUT OF YOUR CAT CRACKER

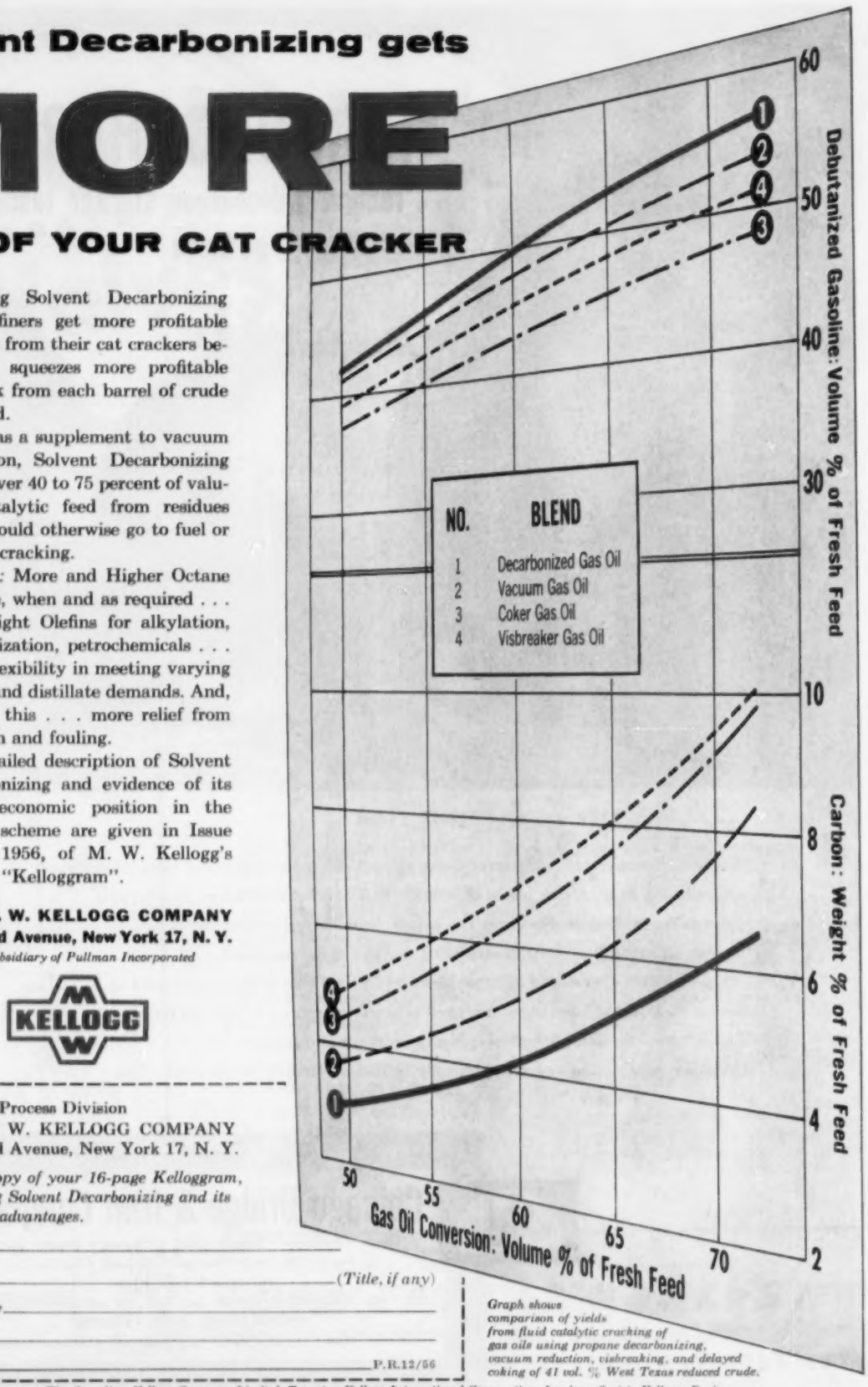
Kellogg Solvent Decarbonizing helps refiners get more profitable products from their cat crackers because it squeezes more profitable feedstock from each barrel of crude processed.

Used as a supplement to vacuum distillation, Solvent Decarbonizing can recover 40 to 75 percent of valuable catalytic feed from residues which would otherwise go to fuel or thermal cracking.

*Result:* More and Higher Octane Gasoline, when and as required . . . More Light Olefins for alkylation, polymerization, petrochemicals . . . More Flexibility in meeting varying fuel oil and distillate demands. And, with all this . . . more relief from corrosion and fouling.

A detailed description of Solvent Decarbonizing and evidence of its strong economic position in the process scheme are given in Issue No. 3, 1956, of M. W. Kellogg's 16-page "Kelloggram".

**THE M. W. KELLOGG COMPANY**
**711 Third Avenue, New York 17, N. Y.**
*A Subsidiary of Pullman Incorporated*




*Graph shows comparison of yields from fluid catalytic cracking of gas oils using propane decarbonizing, vacuum reduction, visbreaking, and delayed coking of 41 vol. % West Texas reduced crude.*

Refinery Process Division
THE M. W. KELLOGG COMPANY
711 Third Avenue, New York 17, N. Y.

*Send copy of your 16-page Kelloggram, describing Solvent Decarbonizing and its economic advantages.*

Name_____

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Address_____

P.R.12/56

*The Canadian Kellogg Company Limited, Toronto • Kellogg International Corporation, London • Societe Kellogg, Paris*
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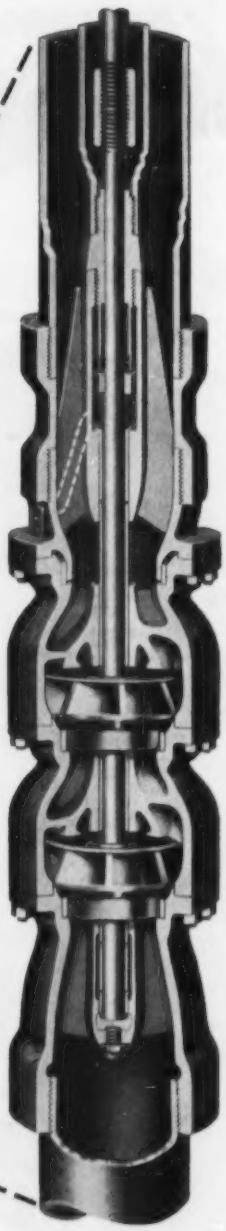
# Precision Built from Performance-Proven Design



The basic design of Layne vertical turbine pumps has been tried and proved under all kinds of operating conditions, both good and bad, the world over.

The finished pumps are produced by skilled craftsmen, in one manufacturing plant, using highest standards—Layne standards.

Industries, municipalities and agriculturalists can rely on the fact that it is prudent and safe to rely on Layne.

For example, consider Layne pump bowls—the very heart of a pump.—

★ Designed by top flight hydraulic engineers, the best available anywhere.

★ Heavy, rugged construction to give long service under gruelling conditions.

★ Clean, smooth flowing water passages in intermediates and hand-finished impellers for high operating efficiencies throughout long operating life.

★ Careful and continuous production control from design board to shipping crate—nothing left to chance.

★ Produced with the prime objective of pumping water at minimum operating cost—BETTER BUILT FOR BETTER SERVICE.

**LAYNE**
**& BOWLER, INC.**
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**Water Wells • Water Treatment**
**Vertical Turbine Pumps**

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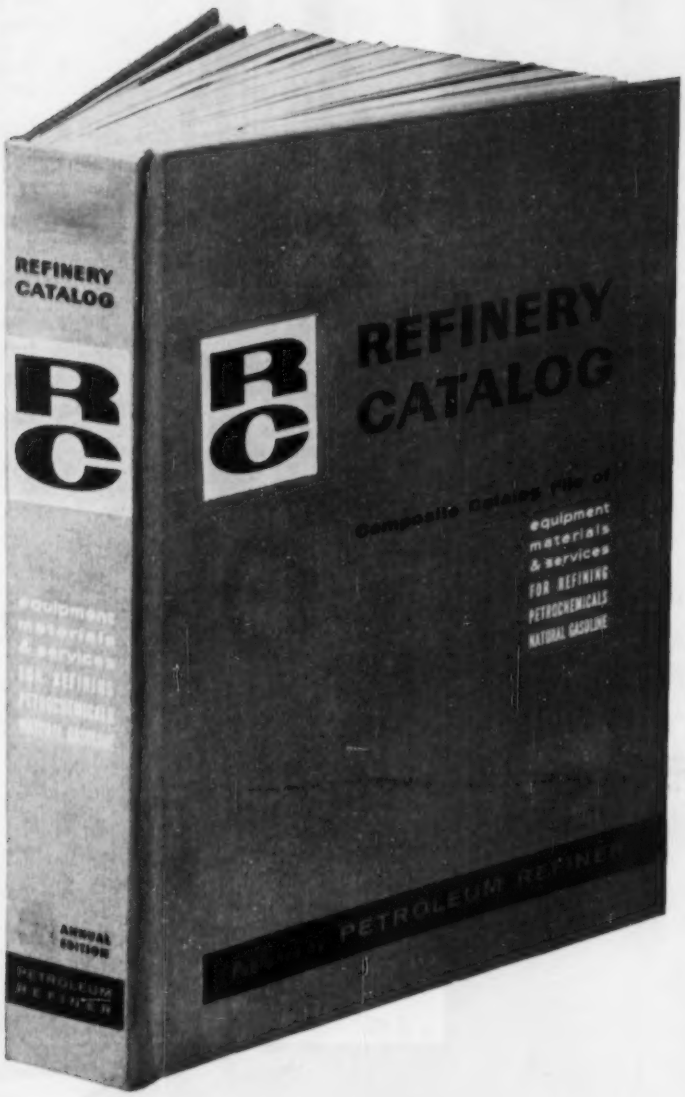
Here's how the REFINERY CATALOG's 1956 Edition appears, with new cover design featuring a large "RC" for easy identification.



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When you have to make fast, accurate buying or specifying decisions, use the REFINERY CATALOG. It is the Refining Industry's universal equipment guide . . . containing the information you need for adequate comparison on hundreds of different types of products and services.

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# The REFINERY CATALOG

**Published annually by PETROLEUM REFINER, Gulf Publishing Company**

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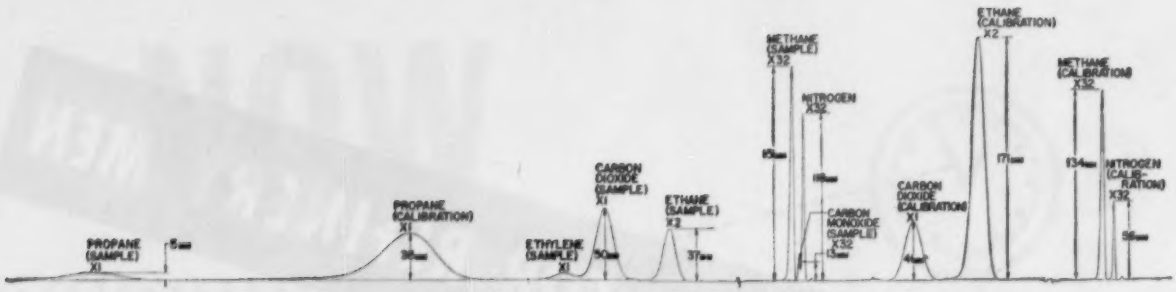


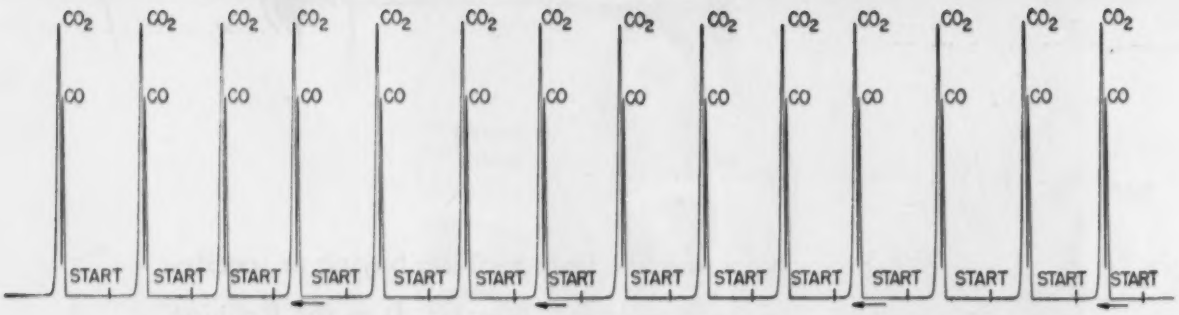

## MANUFACTURED GAS SAMPLE

| | |
|---|---|
| **Sample Volume** | **1 cc** |
| **Column** | **P-E type "J" (2 meters)** |
| **Carrier Gas** | **Helium** |
| **Temperature** | **25°C.** |

This fractogram shows an analysis of a manufactured gas by "intermix calibration" technique (the introduction of a standard gas of known composition into a sample run). Accurate and rapid quantitative results are obtainable since the ratio of corresponding peak heights is equal to the ratio of the component concentrations. Results:

| | | | |
|---|---|---|---|
| **Methane** | 64.0 | **Ethane** | 2.2 |
| **Nitrogen** | 21.0 | **Ethylene** | 0.2 |
| **Carbon Dioxide** | 2.5 | **Propane** | 0.5 |
| **Carbon Monoxide** | 3.0 | **Hydrogen** | 6.6 |

Figures for Carbon Monoxide and Ethylene were obtained by internal normalization, Hydrogen by the difference. If desired, Hydrogen may be determined by a separate analysis. A liquid partition column is used for analysis of the heavier ends. (X values represent step attenuations of recorder sensitivity.)




## PEAK HEIGHT REPRODUCIBILITY

| | |
|---|---|
| **Sample Volume** | **1 cc** |
| **Column** | **P-E type "D" (2 meters)** |
| **Carrier Gas** | **Helium** |
| **Temperature** | **25°C.** |

Accuracy of gas analysis is dependent upon reproducibility of sample volume. The series of runs above demonstrate the unsurpassed sample metering precision of the Perkin-Elmer gas sampling system for the Models 154 and 154-B Vapor Fractometer.

*New P-E Model 154-B Vapor Fractometer gives*

# PRECISE FUEL GAS ANALYSES AT LOW COST

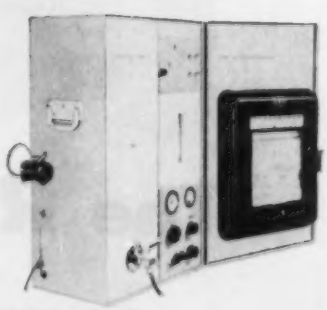
P-E's Model 154-B Vapor Fractometer, based on the principles of gas chromatography, will perform an analysis of a complex mixture of fuel gases—from hydrogen through the pentanes—in less than 60 minutes. Results equal or exceed those obtainable by expensive spectrometric methods, yet initial investment and operating costs are far less—by a factor of at least 10!

P-E feels that this powerful tool will find as broad applications in the chemical industry as any analytical method in existence today and will completely dominate the gas analysis field within the next five years.

If you're interested, write us for a preprint of "Fuel Gas Analysis by Vapor Fractometry (Gas Chromatography)," V. J. Coates and N. Brenner. Our sales engineers are ready to assist you in applying the Vapor Fractometer in your operation.

**Perkin-Elmer** CORPORATION

NORWALK, CONNECTICUT



**The Model 154-B Vapor Fractometer with recorder in matching cabinet (right) is priced at $2,385.00. Also available without recorder. Send for descriptive bulletin.**

# ASK THE EXPERTS... about ORBIT VALVE performance and quality

Valves get a fast, unbiased appraisal by the experts — men who buy and use them. The best recommendation Orbit could ask for is the fact that these experts regularly specify Orbit Forged Steel ASA Class Valves. They are used for many processes and applications in petrochemical and petroleum hydrocarbon plants. The performance of Orbit valves proves the importance of buying valves engineered, designed and built for specific uses.

Full Round Opening sizes available in Flanged & Screw End ASA Class, 1, 1½, 2, 2½, 3 & 4 inches, beginning with 300 lb., thru 2500 lb., Carbon & Stainless Trim.

Venturi Type — available sizes: Flanged End only, ASA Class, 2, 2½, 3, 4 & 6 inches, beginning with 150 lb., thru 2500 lbs., Carbon & Stainless Trim.

## ORBIT VALVE COMPANY

**P. O. BOX 699 • TULSA 1, OKLAHOMA**

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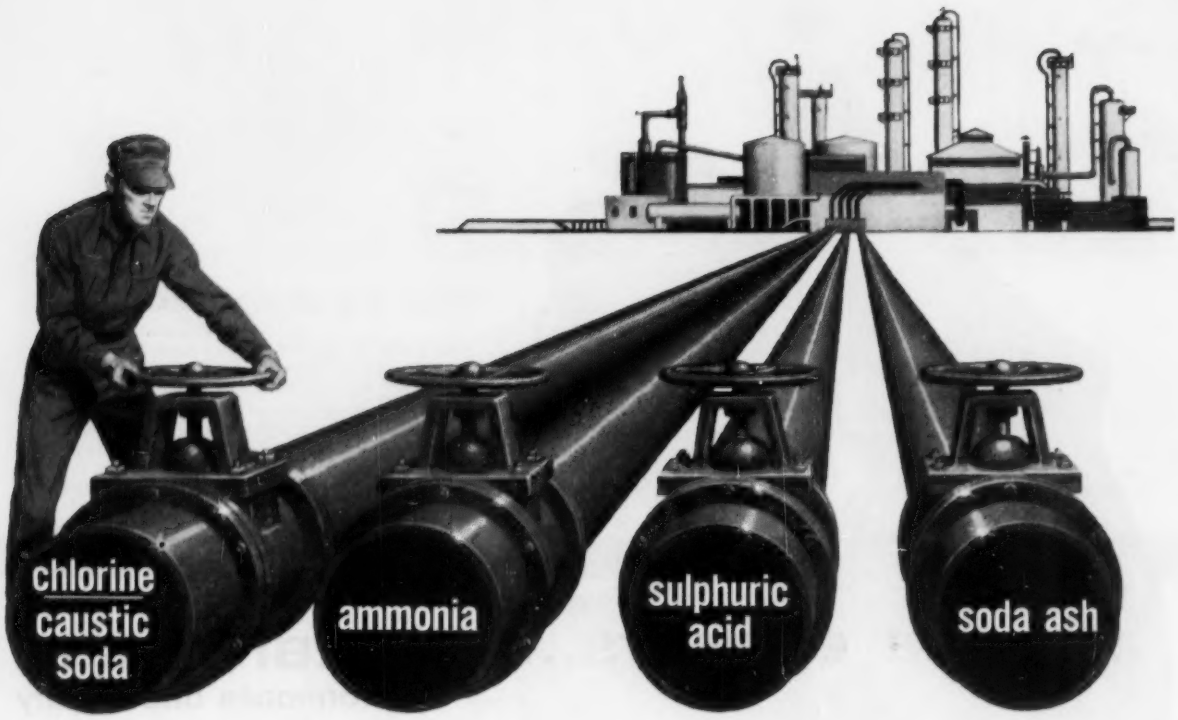


# you can be on our "pipe line"

Want to smooth out your chemical supply problems? Tap into the Olin Mathieson "pipe lines." You'll see what our multi-plant production facilities can mean to you.

The effect of a number of producing points is to balance out local shortages and surpluses. In one instance, a serious chlorine shortage on the Gulf of Mexico was relieved by an excess in Canada. Each of the five plants between shipped into the next plant supply area to the South, setting up a chain reaction which released the needed tonnage on the Gulf.

Our combination of multi-plant facilities and an imaginative approach to the logistics of the chemical industry can prove invaluable to you. Discuss it now with an Olin Mathieson representative or write the Chemicals Executive Office in Baltimore.

MATHIESON

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OLIN MATHIESON CHEMICAL CORPORATION
INDUSTRIAL CHEMICALS DIVISION · BALTIMORE 3, MD.

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INORGANIC CHEMICALS: Ammonia · Bicarbonate of Soda · Carbon Dioxide · Caustic Potash · Caustic Soda · Chlorine · Hydrazine and Derivatives · Hypochlorite Products · Muriatic Acid · Nitrate of Soda · Nitric Acid · Soda Ash · Sodium Chlorite Products · Sulphate of Alumina · Sulphur (Processed) · Sulphuric Acid
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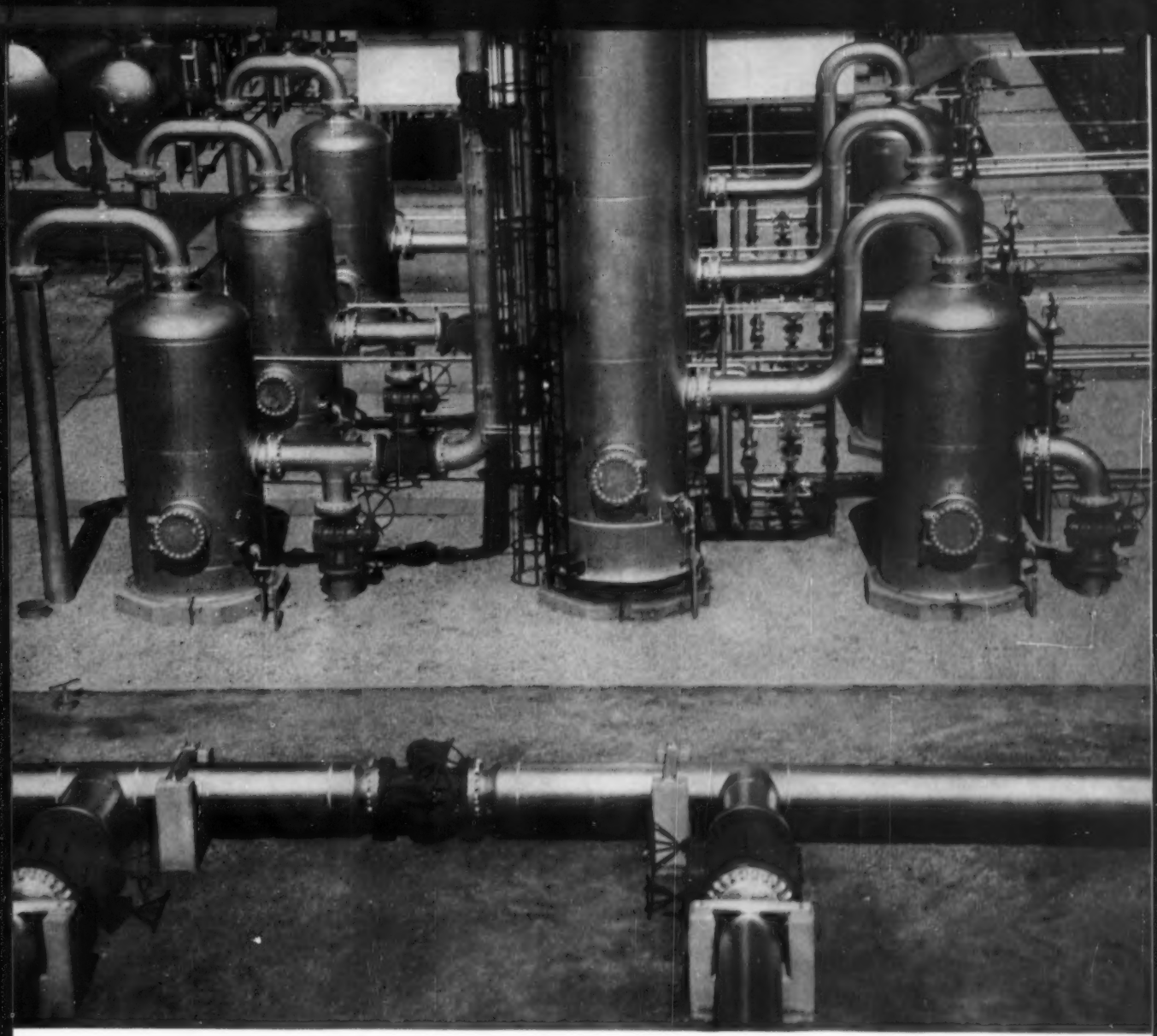


# *How much does safety cost?*

You don't pay extra for the inherent safety of Rockwell-Nordstrom valves. Actually, their price is often lower than ordinary valves. Their cost to use, year after year, is much lower because lubricant stops trouble before it starts.

Forty years of outstanding performance have proven you can't buy a safer valve than Rockwell-Nordstrom. Pressurized lubricant sealing means positive, leakproof control on lightest gases. Streamlined thru-port design minimizes pressure loss on even heavy slurries. Quarter-turn operation is two to five times faster than ordinary valves. You *know* you are safe when you specify Rockwell-Nordstrom valves. Rockwell Manufacturing Company, Pittsburgh 8, Pennsylvania.

*Available at leading suppliers . . . everywhere.*

## ROCKWELL-Nordstrom VALVES

**Lubricant Sealed for Positive Shut-off**

40th Year *of lubricated plug valve leadership*

# *For power operation . . . clearly superior*

Rockwell-Nordstrom valves' quarter-turn operation allows the use of less complicated (and less costly) operators. Lubrication greatly reduces torque. The thin, tough film of *pressurized* lubricant that forms the leakproof seal also cuts maintenance and down time by stopping trouble before it starts.

For electric, pneumatic or cylinder operation, Rockwell-Nordstrom valves perform better, longer, for less money. For more information, write: Rockwell Manufacturing Company, Pittsburgh 8, Pennsylvania.

*Available at leading suppliers . . . everywhere.*

## **ROCKWELL**-Nordstrom **VALVES**

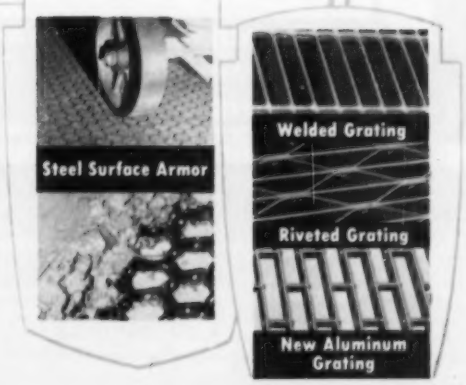
**Lubricant Sealed for Positive Shut-off**

40th Year *of lubricated plug valve leadership*

*every hour, every minute, every second . . .*

**prolong the life of vessel liners and decrease frequency of costly shutdowns with KLEMP HEXTEEL**

Other world-acclaimed Klemp products:




**KLEMP METAL GRATING CORPORATION**

6641 South Melvina Avenue • Chicago 38, Illinois

PArtsmouth 7-6760

Gentlemen:
Kindly send me a FREE copy of:

☐ "Serving the Oil Industry for Over 40 Years"

☐ Klemp Data & Specification Manual (describing Klemp's complete line of products)

Name_____

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City_____ Zone_____ State_____

Phone_____



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*exhaustive tests prove:*

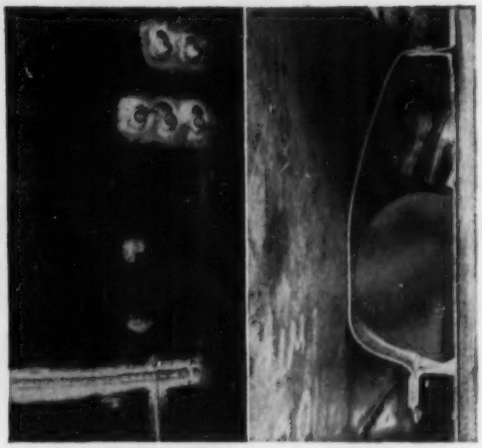
# 36 YEARS FROM TODAY

# TUBESEALS* NOW IN FLOATING ROOF TANKS WILL OPERATE AS EFFICIENTLY AS THEY DO TODAY!

**WE DOUBT this can be claimed for any other floating roof seal!**

To determine the efficient life-expectancy of the Hammond Tubeseal in service, tests were made under the worst possible conditions to which a floating roof seal can be subjected. The Tubeseal was moved across very rough rivet heads, erection burrs and abrasive weld surfaces, for a total travel of 70,000 feet. This is equivalent to a normal wear of *more than 36 years in actual service.* Moreover, as the tests were run dry, there was the added disadvantage of the absence of lubricating effect normally created by wetted surfaces. Upon completion of these rigorous tests, the scuff band had only worn through the ribs and had barely penetrated through the material, leaving two-thirds of the stock intact; proof that the Tubeseal is unimpaired after traveling 70,000 feet.

The 36 year life-expectancy of a Hammond Tubeseal assumes no mechanical accident and is arrived at in the following manner: Each year a floating roof, in normal service, makes about 48 trips to and from top and bottom of tank. The roof of a 40 foot tank, therefore, will travel 1920 feet per year. Assuming 1920 feet of travel per year (based upon full depth of travel) and applying our accelerated wear test, the Tubeseal will be serviceable for at least 36 years 5½ months.



**THE TUBESEAL TEST:**

| | |
|---|---|
| total travel | 70,000 feet |
| travel over vertical weld | 46,400 feet (on same line) |
| Horizontal welded seam crossed | 21,200 times |
| Flat head rivets crossed | 63,600 times |

CONDITION OF TUBESEAL AFTER TEST: Scuff band had worn through ribs and had barely penetrated into the main material, leaving ⅔ of stock intact.

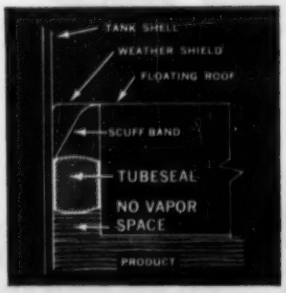
Tests were conducted dry with no aid of lubricant normally resulting from stored product.

*Photos show projections used for test. Included are 16"of ⅜" horizontal weld—24" of sharp, irregular vertical weld—2 erection burrs—3 ¾" flat head rivets and 2 ¾" cone head rivets.*

**THE HAMMOND TUBESEAL**
***is the most efficient and positive seal known.***

***it features:***

***no moving parts***
***no mechanical maintenance***
***climate proof***
***non-corrodible***
***can operate to bottom of tank or above the top***
***no vapor space below the seal***
***entire circumference has tight seal under pressure at all times***
***longer working life expectancy***




**NO ROOM FOR VAPORS**
**NO EVAPORATION**
**NO CORROSION**

**patented* ***Write for bulletin TS***

HAMMOND TUBESEAL — THE MOST EFFICIENT AND POSITIVE SEAL KNOWN

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# It's in the Bag!

## Fresh, Clean Ink for a Year of Trouble-free Recording

★ You won't have any messy, time-consuming re-inking of pens on the new Bailey Recorders. The entire system is white-glove clean—hermetically sealed, non-evaporating, non-corrosive. Gone is any chance of sludge or oxide formation. Gone are clogged pens, interrupted records, unsightly splashes.

The transparent plastic ink sacs are changed once a year—that's all. Capillary tubing carries fresh, clean ink to the pens continuously without any day-to-day attention.

This exclusive new inking system* is only one of the many time-saving, money-saving distinctive features of the new Bailey Recorder.

Ask for Product Specification E12-5.

*Now available for the New Bailey Recorder only.

**ONLY BAILEY OFFERS ALL THESE ADVANTAGES IN A SINGLE RECORDER**

- Pre-calibrated plug-in receiver units
- Up to four pneumatic or electronic receivers —or two receivers and two integrators
- Any four variables on one chart—easily read and interpreted
- A full year's ink supply at one loading
- Faster ordering—from stock
- Minimum inventory of parts
- Minimum instrument investment for process cycle expansion or alteration

**BAILEY METER COMPANY**
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*Controls for Power and Process*

BAILEY METERS
*Controls for*
TEMPERATURE
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GAS ANALYSIS
FLOW · LEVEL
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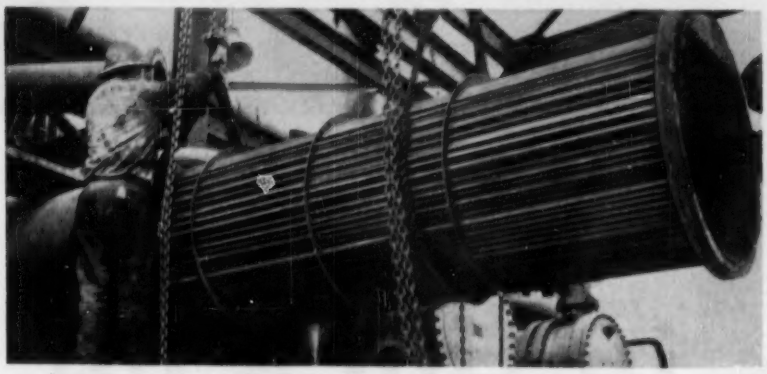
BRIDGEPORT BRASS COMPANY

CONDENSER AND HEAT EXCHANGER TUBE EDITION

# COPPER ALLOY BULLETIN

Bridgeport BRASS CO. MILLS IN BRIDGEPORT, CONN. AND INDIANAPOLIS, IND.—IN CANADA: NORANDA COPPER AND BRASS LIMITED, MONTREAL



Replacing a copper alloy tube bundle after cleaning.

## How to Reduce Exchanger Maintenance Costs by Using Performance Records

Although tube and shell heat exchangers fall into well-defined classes of design and operation, the variables in each exchanger situation make it an "individual" in respect to performance or corrosion failure. For this reason, comprehensive and continuing performance records on each exchanger are essential in achieving maximum operating efficiency and productivity.

### Why Keep Records?

The primary purpose is to establish a performance pattern which will suggest a minimum though adequate maintenance schedule. Proper records should also help to detect variations in operating conditions which, though slight, may require significant changes in maintenance scheduling.

### Tube Selection Important

Such performance records can also help determine whether or not the best exchanger design or tube alloy is being used. For example, although Bridgeport Arsenical Admiralty or Arsenical Muntz would ordinarily be indicated for saline or brackish cooling water, adequate records will often reveal that Bridgeport Duplex, Copper, Red Brass, Arsenical Aluminum Brass, Duronze IV or occasionally 70-30 Cupro Nickel would be more economical.

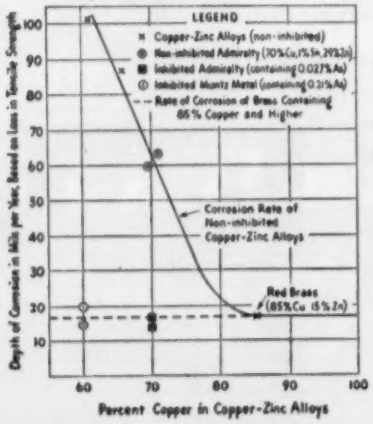
### Preplanning and Scheduling

Another benefit in adequate record-keeping is in the preplanning of maintenance repairs. The nature and extent of the maintenance can be known and prepared for previous to shutdown, permitting servicing with minimum loss to operating time. Likewise, sufficient lead time can be allowed in ordering tube replacements or in obtaining qualified technical help in determining the proper tube alloy to use if this is indicated.

### Watch Those "Variables"

A file of records does not in itself constitute a maintenance program. Instead, critical evaluation must be made of each report so that existing maintenance schedules may be confirmed or altered. A particularly keen eye should be kept on those variables not normally recorded by the operating staff. Minor changes in water composition or product streams may not be important in production, but may significantly affect fouling or corrosion rates. For instance, in petroleum refining and petrochemical processing, the hydrocarbons have virtually no effect on copper and its alloys. But the presence of sulfides, chlorides, acids, ammonia, gases and moisture influenced by variations in temperatures, velocity and pressure will have an important effect on corrosion. Thus, where conditions such as these are detected, and where operational adjustments are not feasible, consideration should be given to the use of the other copper-base alloys or Duplex tubing.

CORROSION RATE of INHIBITED and NON-INHIBITED COPPER-ZINC ALLOYS in 1% Cupric Chloride Solution for 70 Days at Room Temp.




### Records Help Lick Dual Corrosion

Another advantage of adequate record-keeping is in high-lighting the need for maintenance-reducing techniques. For example, under some conditions, the use of higher grade components, such as Duplex tubes, proves economical when yearly costs are totaled up. The experience of one refinery demonstrates this point. In an exchange between ammonia and hydrogen sulfide bearing propane gas and river water, the continual failure of steel and red brass tubes made it necessary to retube the exchangers every one or two years. A change-over to Bridgeport Duplex Tubes—with low carbon steel on the product side and red brass on the water side—resulted in an average life of from 6 to 10 years.

### Technical Service

These are just a few of the advantages of keeping maintenance records on performance and how they can provide a clue toward solving your corrosion problems. For more specific help, the advice and experience of Bridgeport's Technical Service and Corrosion Laboratories are at your service through your nearest Bridgeport Sales Office. This service, plus Bridgeport's extensive selection of tubes and alloys, will enable you to meet your needs faster, easier and more economically. (842)

### Further Help From Bridgeport's Condenser Tube Handbook

A wealth of practical detailed information on tube condensers and heat exchangers is contained in the Bridgeport *Condenser Tube Handbook*. Anyone concerned with the specifications, operation or maintenance of such units will find it an invaluable addition to his reference library. Write for your free copy.

# The incorrect power cable can cost you a fortune

In buying thermoplastic wires and cables, selection of the right compound for your specific installation conditions is all-important. Use of an incorrect cable construction can jeopardize the flow of production in your refinery or plant. Hundreds of available thermoplastic compounds have made selection difficult. But a careful study of the various Okoseal (polyvinyl chloride) and Okolene (polyethylene) insulations and sheaths compounded to Okonite's own formulas will enable you to select the specific cable construction best suited for your environment, such as: salt water, petroleum oils, paraffinic hydrocarbons, alcohols, mineral acids, fixed alkalies, ketones, esters, halogenated hydrocarbons. Judicious choice of the proper Okonite cable will provide a longer-lived electrical system.

**NEW Okonite Technical Bulletins offer specific information**

Especially compiled for the refining, natural gas, and petrochemical fields, the following bulletins give complete technical information, including dimensions, on Okonite plastic cables for power, control, machine tools, lighting circuits, motor leads, switchboards, communications and cathodic protection.

***available with either copper or aluminum conductors***

**THE OKONITE COMPANY, Passaic, N. J.**
**Kindly send me the free bulletins checked below.**

- ☐ **BULLETIN 2120**—Insulated Power and Control Cable—600 Volts (Okoseal 100)
- ☐ **BULLETIN 2121**—Machine Tool and Switchboard Wire—600 Volts (Okoseal 200)
- ☐ **BULLETIN 2122**—High Ambient Petroleum and Chemical Resistant Wire—600 Volts (Okoseal 300)
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- ☐ **BULLETIN 2127**—Cathodic Protection Cable (Okolene 400)
- ☐ **BULLETIN 2128**—Relative Environmental Performance Data for Plastic Insulations and Sheaths

**NAME**..... **TITLE**.....

**COMPANY**.....

**ADDRESS**.....

**CITY**..... **STATE**.....

***where there's electrical power...there's*** **OKONITE CABLE**

4323

**. . . there's enough difference to make ALL the difference**

This is just one inspection of extrusion dies through which a cast billet heated to a rigidly controlled temperature is hot extruded into a "tube shell" . . . from which Scovill Heat Exchanger Tube is subsequently cold-drawn.

One of the most highly skilled and critical jobs in the process is that of finishing and maintaining these dies. The smooth, clean surfaces of resulting shells are essential assurance of highest quality in finished tubes.

It is needless to tell Scovill customers that, while *correct alloy selection* is important to efficient exchanger operation, of equal importance is the *uniformity and soundness of tubes* themselves. Scovill Technical Service and tube production methods, considered by many the very best in the industry, can give you complete assurance on both these essential counts.

Scovill Heat Exchanger Tube is available in a comprehensive range of standard alloys (listed below).

Scovill Manufacturing Company, Mill Products Division, 99 Mill Street, Waterbury 20, Connecticut. Phone Plaza 4-1171.

**SCOVILL** **HEAT EXCHANGER TUBE**

FOR APPLICATIONS FROM MARINE TO PETROCHEMICAL . . . FROM COMPRESSOR INTERCOOLERS TO "CAT-CRACKER" EXCHANGERS.

Phosphorized Admiralty • Admiralty • Arsenical Admiralty • Naval Brass • Red Brass, 85% • Deoxidized Copper
Arsenical Copper • Cupro Nickel 10%-20%-30% • Aluminum Brass • Aluminum Bronze, 5% • Muntz Metal • Duplex Tube

tscso



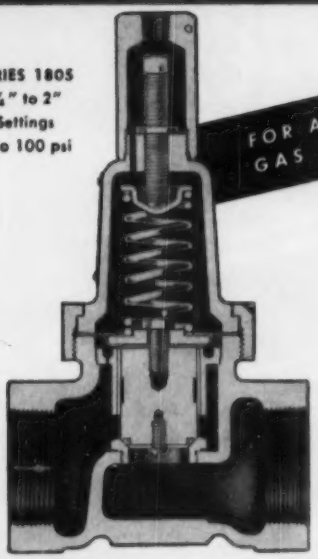
For more data on advertised products, use Readers' Service Cards, last page.

# look to FISHER for genuine relief from overpressure worries!

Hundreds of plants have found Fisher compact and self-contained relief valves the answer to their relief or back pressure control problems. Whether it may be a rather unusual problem, or simply to protect your gas system for safety reasons, or possibly to relieve excess pressure from a pump, by-passing back to suction, the chances are Fisher could solve your problem. May we suggest you contact our representative in your area?

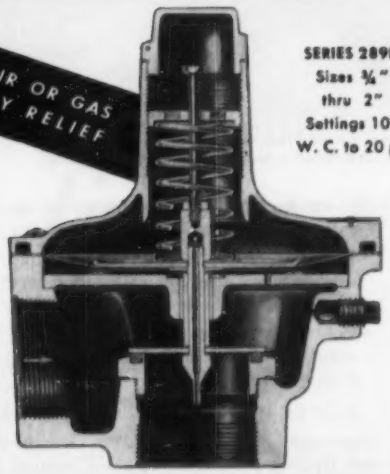
**SERIES 1805**
**¾" to 2"**
**Settings**
**5 to 100 psi**

FOR AIR OR GAS RELIEF



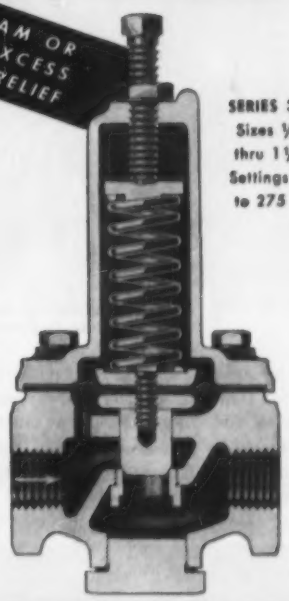
FOR AIR OR GAS SAFETY RELIEF

**SERIES 289H**
**Sizes ¾"**
**thru 2"**
**Settings 10"**
**W. C. to 20 psi**



FOR STEAM OR LIQUID EXCESS PRESSURE RELIEF

**SERIES 372**
**Sizes ½"**
**thru 1½"**
**Settings 10**
**to 275 psi**



**FISHER GOVERNOR COMPANY**
**MARSHALLTOWN, IOWA • WOODSTOCK, ONTARIO**
LEADS THE INDUSTRY IN RESEARCH FOR BETTER PRESSURE AND LIQUID LEVEL CONTROL

FISHER
*Since 1880*



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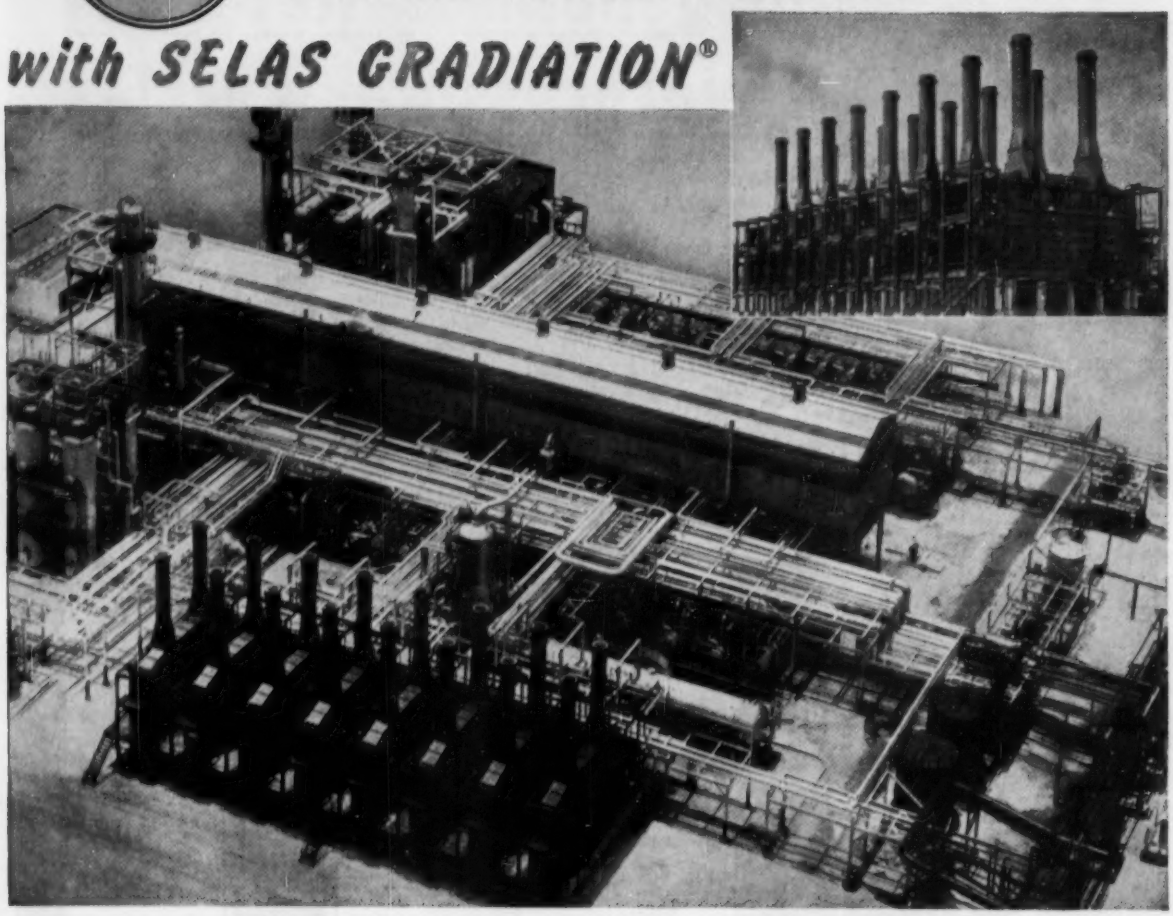
GULF

# CRACKS THREE ETHYLENE FEED STOCKS INTERCHANGEABLY . . .

## with SELAS GRADIATION®



Gulf Oil Corporation's new ethylene plant at Port Arthur, Tex., designed and constructed by Stone & Webster Engineering Corporation. Eight Selas Gradiation heaters are in center foreground.

The world's largest ethylene-producing plant benefits from the versatility of Selas Gradiation heaters. Three separate feed stocks—propane, ethane and propane-propylene mixtures—have been processed interchangeably in all of the eight Selas furnaces.

Operating results on all three feed stocks in the Gulf plant confirm that these Selas heaters provide:

- "On stream" periods, without shutdowns, well in excess of 30 days.
- High conversions and selectivity.
- Optimum conditions, even with extreme variations in feed stock.

Zone control of heat input, enabling Selas heaters to meet any time-temperature curve in pyrolytic or catalytic reactions and high-temperature preheating, is featured by:

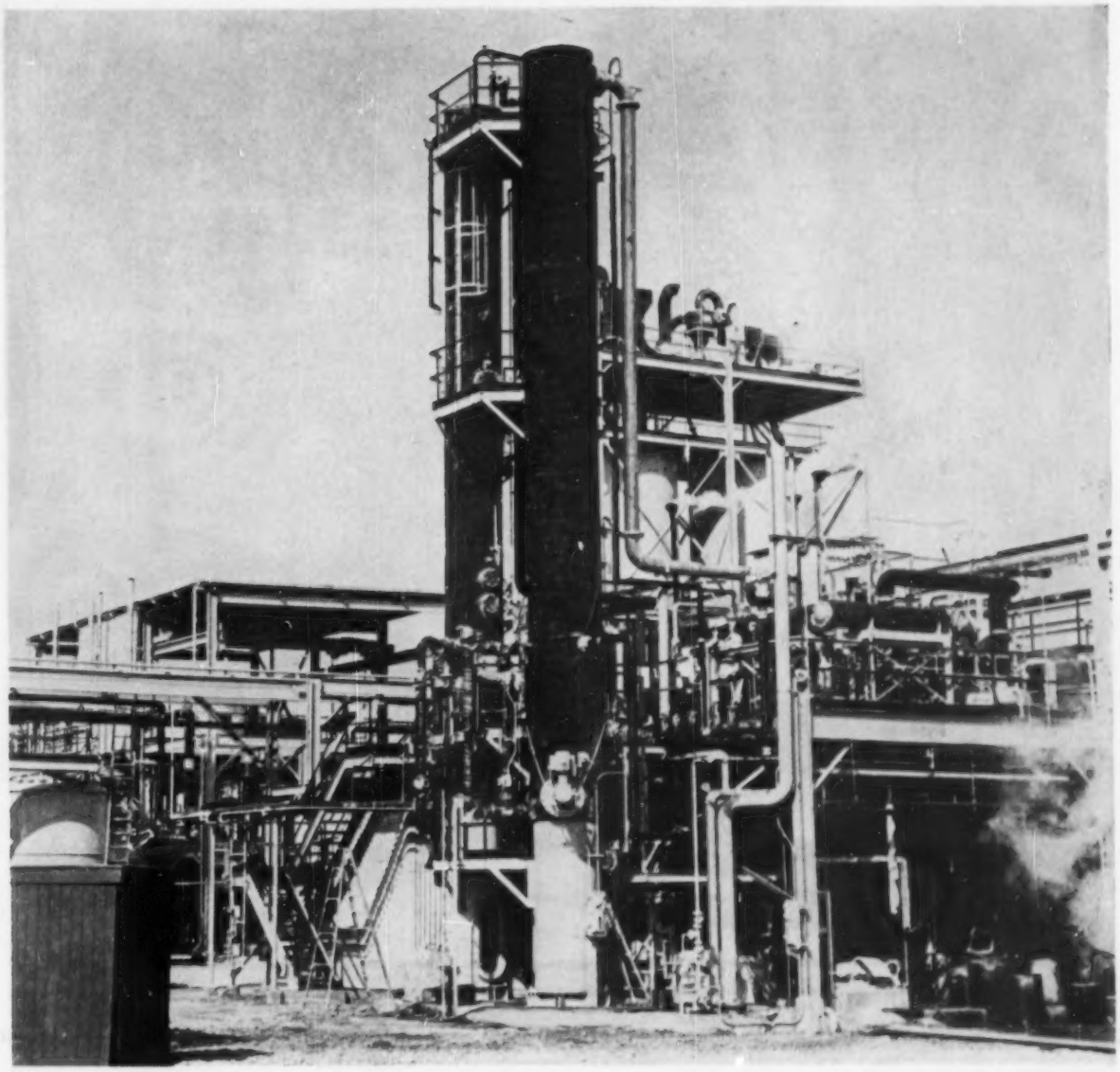
- Uniform heat distribution on the entire tube surface which extends tube life by eliminating local overheating and material degradation at the tube wall.
- Controlled combustion, with little or no excess air to cause external oxidation of the tubes . . . no lag in response to controller demand.

*Send for copy of reprint, "Try the Gradiation Heater for Economical Ethylene Production" and Bulletin 812, "Gradiation Heating for Petroleum and Chemical Processing."*

**SELAS** CORPORATION OF AMERICA DRESHER, PENNSYLVANIA

*Heat and Fluid Processing Engineers*

DEVELOPMENT • DESIGN • CONSTRUCTION



# Product spoilage eliminated in phenol plant by *Carpenter* Stainless Tubing!

Oxide discoloration was imparted to the phenol by carbon steel tubes first used in this phenol plant. A change to Carpenter Stainless Tubing has ended this problem permanently. Compare Carpenter quality, and you'll install Carpenter Stainless Tubing for your own processing applications.

MEMBER

**The Carpenter Steel Company, Alloy Tube Division, Union, N. J.**

*Export Dept.: The Carpenter Steel Co., Port Washington, N.Y.—"CARSTEELCO"*

**Carpenter**

**Stainless Tubing & Pipe**



For more data on advertised products, use Readers' Service Cards, last page.

*. . . 52 pages on—*

**TABLE OF CONTENTS**

- Uses
- Physical properties—tables and graphs
- Chemical properties
- Specifications
- Handling and storage
- Physiological properties
- Shipping specifications
- Analytical procedures
- Bibliography

Write on your letterhead for this new book—and for samples of our material. It's the purest available commercially—free of impurities that cause corrosion and interfere with reactions. Stocks nationwide. Technical service—no obligation.

Dept. EA 1-21-1

Allied Chemical — NITROGEN DIVISION

40 Rector Street, New York 6, N. Y.

**Ethanolamines • Ethylene Oxide • Ethylene Glycols • Urea • Formaldehyde • U. F. Concentrate—85 • Anhydrous Ammonia • Ammonia Liquor • Ammonium Sulfate • Sodium Nitrate • Methanol • Nitrogen Solutions • Nitrogen Tetroxide • Fertilizers & Feed Supplements**



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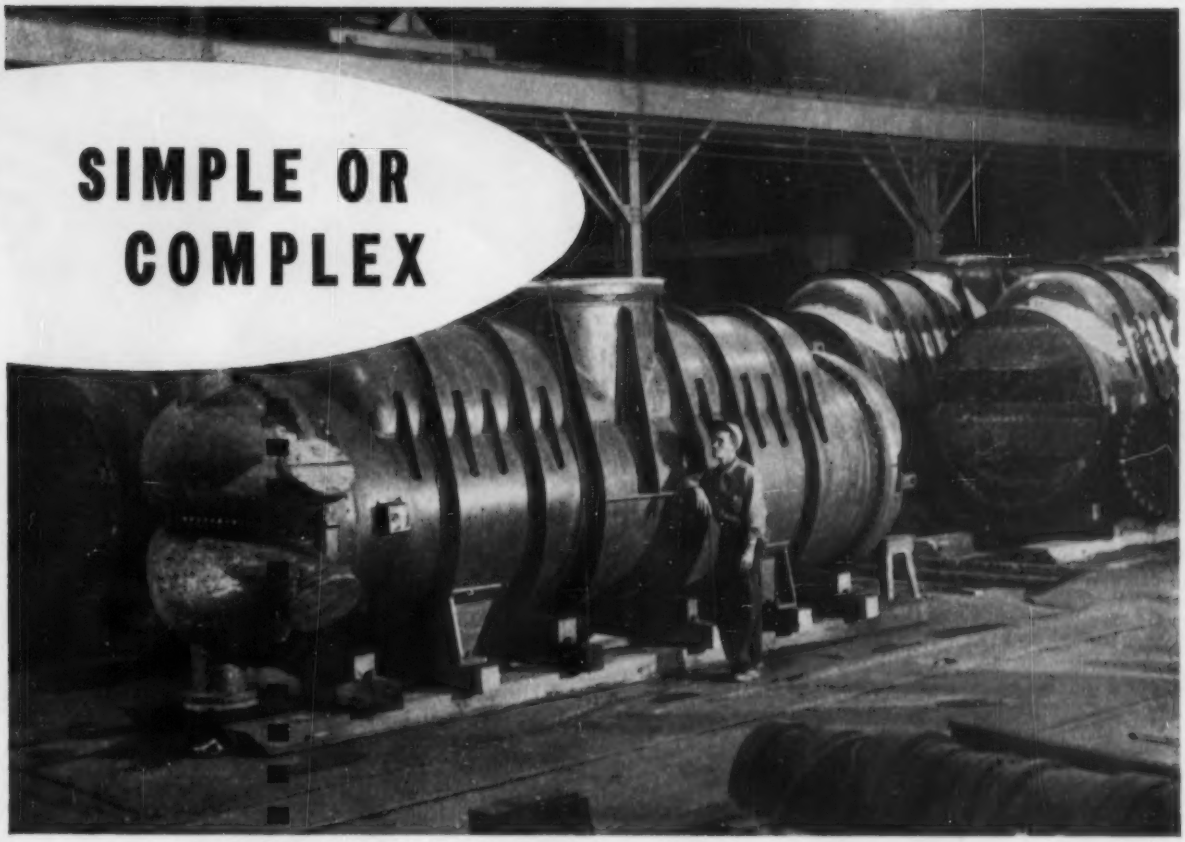


# SIMPLE OR COMPLEX

## *EFCO does it right*

No job is too complicated for Efco's heat-transfer specialists. One reason that Efco does it *right* is its many years of experience in designing and fabricating heat-exchangers for the wide range of temperatures and pressures represented by ethylene plants and platinum catalyst reforming units. We are recognized specialists in handling all grades of carbon, alloy, and stainless steels, nickel, aluminum, and special low-temperature materials.

***EFCO'S FOUR POINT PROGRAM PROVIDES:***

**service-proved engineering design**
**guaranteed job-ratings**
**complete fabricating facilities**
**technical service before, during and after installation**

***ASK OUR GULF COAST CUSTOMERS — THEY KNOW US WELL***

**Write for General Catalog**

**EFCO HEAT TRANSFER EQUIPMENT**
*Engineers and Fabricators, Inc.*
**P. O. BOX 7395** **HOUSTON 8, TEXAS**

EFCO

6102



For more data on advertised products, use Readers' Service Cards, last page.

# FOAMGLAS®

*the cellular, stay-dry insulation*

**STAYS DRY**—Here's how you can prove to yourself that FOAMGLAS does stay dry. Cut a piece from a FOAMGLAS sample. Place it in water. Note how its hermetically sealed glass cells keep it afloat. Weight it down for days, weeks or longer if you like. Remove the weight and it bobs back to the surface . . . proof that the sealed cells have absorbed no water—still have their original insulating efficiency.

## Wet insulation is no insulation . . .

## Prove to yourself that FOAMGLAS stays dry!

### Send for a sample and test it!

Moisture conducts heat! When an insulation begins to absorb moisture, its efficiency nosedives. It's no longer an insulation.

That can't happen to FOAMGLAS. Every block of this unique insulating material is composed of millions of hermetically sealed glass cells. Each cell is an individual insulating unit . . . and each is watertight. Water and vapor are sealed out to insure constant insulating effectiveness.

In a few minutes, in your own office, *you* can prove to yourself that FOAMGLAS *stays dry*. Send today for a free sample and directions for simple "desk top tests" you can perform, as illustrated on this page. You'll soon see why it pays to insulate floors, walls, ceilings, roofs, piping and equipment with FOAMGLAS. You're assured constant, long-lasting insulating efficiency without the headache and expense of insulation replacement.

Vapor-proof

Strong and rigid

Inorganic and incombustible

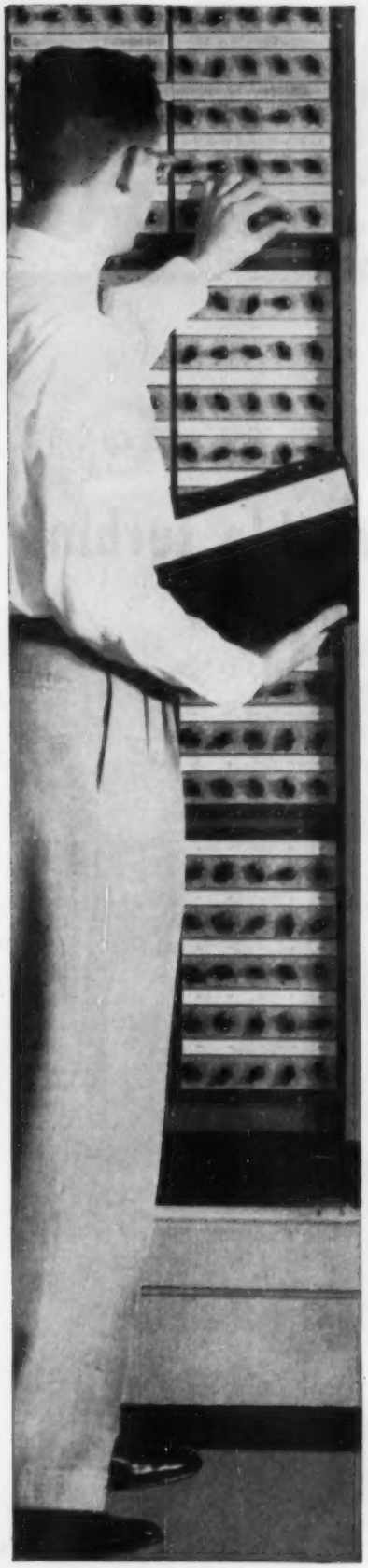
Lightweight

**Pittsburgh Corning Corporation**

Dept. Z-126, One Gateway Center, Pittsburgh 22, Pa.

In Canada: 57 Bloor Street West, Toronto, Ontario

**also manufacturers of PC Glass Blocks**



# Panalog Information Systems guide management in raising plant output and profit

**Panalog 605 Information System supplies management control information.** Now, operating personnel and management can receive organized digital information on any process, instantly and continuously. Information can be presented in a variety of forms for immediate control action as well as for engineering and accounting analysis. A typical presentation method employs an electric typewriter and patented log chart. Readout can also be made on punched or magnetic tape, punched cards, or can be fed directly to computers.

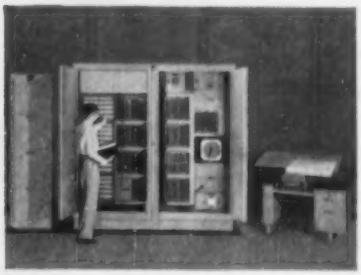
**Periodically logs and continuously scans.** A precision servo measuring system quantizes process variables during automatic, periodic logging. A high-speed electronic measuring system detects off-normal conditions during continuous scanning of all variables. Normal and return-to-normal values are printed in black—off-normals in red. A complete log of all variables as well as a summary of off-normals can be made at any time.

**Completely flexible and expandable.** Panalog components are standardized, packaged modules. The system can be easily expanded or modified in the field. The Panalog 605 is sufficiently flexible to supply digital information for any management requirement.

**Write for literature.** Literature presenting a comprehensive treatment of the Panalog 605 is available. If you wish, a Panellit representative in your area will be happy to discuss the possibilities that a Panalog Information System offers your company.

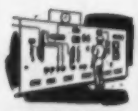
*Full scale, adjustable, high and low off-normal limits are provided for each input variable. Basic system capacity, 200 points with one electric typewriter — can be expanded. Accuracy, ±.25% of full scale range. Logging speed, approximately one line per minute. Scanning speed, five points per second, between logs.*

*Logged values are grouped by processing unit on chart. Audio-visual alarms accompany detection of off-normals. When scanning, off-normal values are identified and printed in separate chart area. Totalized and averaged values as well as plant efficiencies can be automatically computed and recorded by the system.*



U.S. Pat. No. 2,701,748

***Engineered Information Systems For Industry***



*Graphic Panels Control Centers*

*Panalarm Annunciators*

*Panellit Service Corp.*

PANELLIT

**PANELLIT, INC.**

*7415 N. Hamlin Ave., Skokie, Ill.*
*Panellit of Canada Ltd., Toronto 14*

# 5 STEPS

## in making an almost indestructible turbine

The rotor of a Terry solid-wheel turbine is a single forging of special composition steel. It is first rough turned in two operations, as shown, and then two cuts are taken to mill the semi-circular buckets from the solid metal. The wheel at the top has been finished, ready for mounting on the shaft. *The result is a single-piece wheel with no parts to loosen or wear out.*

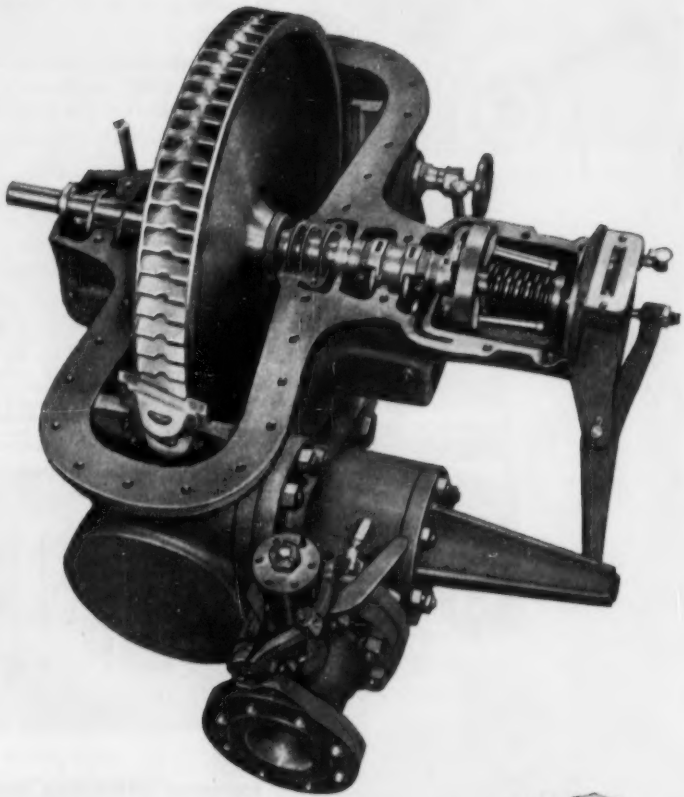
Blade wear, which might occur after many years of usage, is not important, because the power-producing action of the steam takes place on the curved surfaces at the backs of the buckets. Thus wear does not materially affect horsepower or efficiency.

The blades can't foul. They have a one-inch clearance, and are further protected by the projecting rims at the sides of the wheel.

The Terry solid-wheel turbine is an extremely reliable piece of equipment. Write for details—today. Ask for a copy of bulletin S-116.

**THE**
**TERRY STEAM TURBINE CO.**
TERRY SQUARE, HARTFORD 1, CONN.

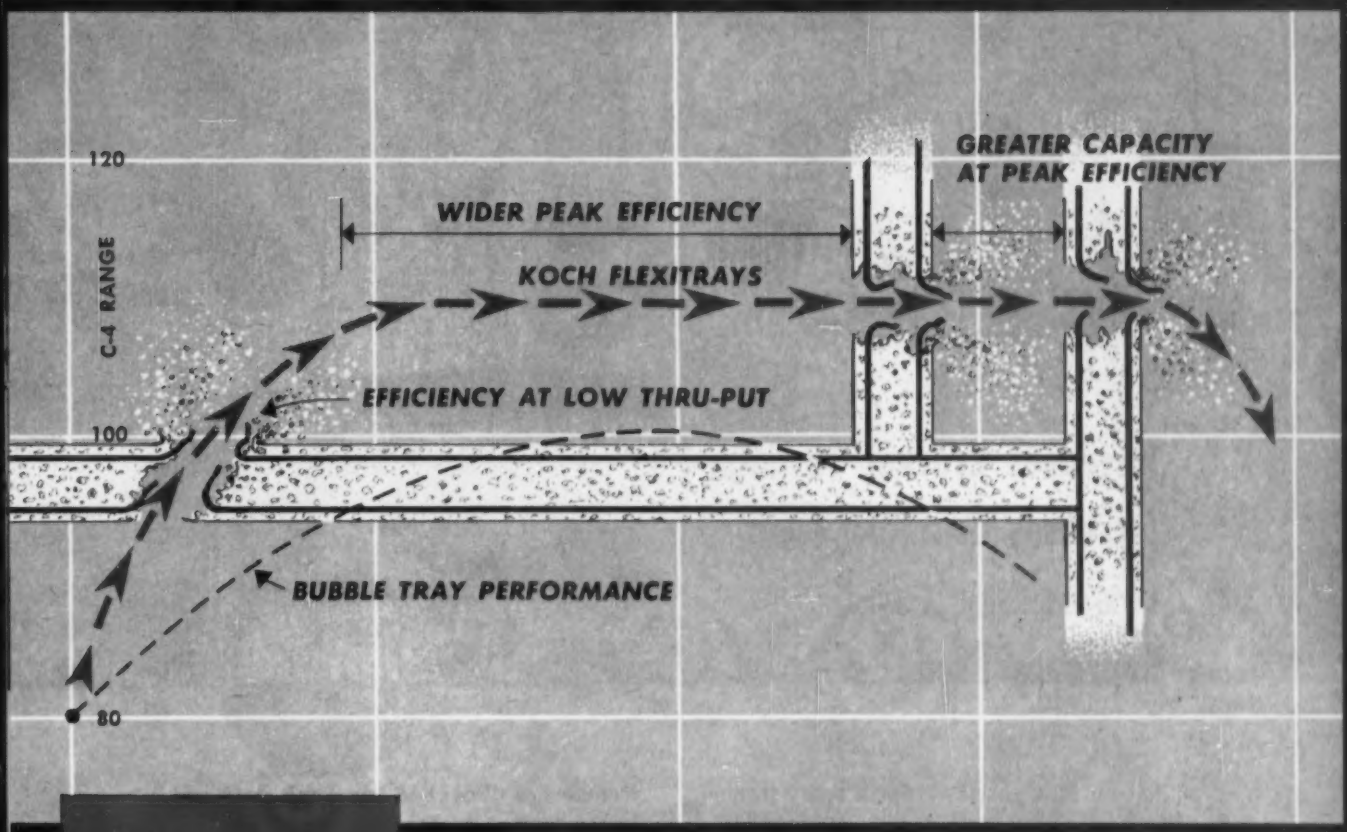
TT-1204

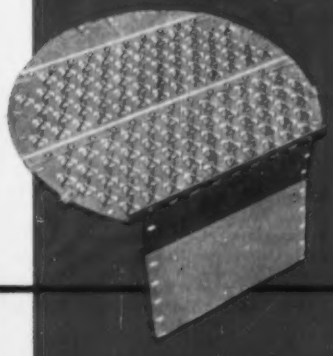


TERRY

# KOCH FLEXITRAYS

## BREAK 3 BARRIERS



**Investigate** the accomplishments of this new low-cost tray in all services. Be among the leaders to use this fine new tray. More than 300 installations to date. Wire, write, or phone us on its application to your problems.

## KOCH ENGINEERING COMPANY, INC.

DESIGNERS AND FABRICATORS OF MODERN TRAYS
321 WEST DOUGLAS • WICHITA 2, KANSAS

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**Pittsburgh, Pennsylvania Representative**: D. D. Foster Company, 501 Alcoa Building
**West Coast Representative**: Jacobs Engineering Company, Pasadena: RYan 1-9373, Oakland: TEmplebar 2-5391
**Illinois Representative**: M. B. Fisher, 1521 Courtland Avenue, Park Ridge, Illinois

# How Solvent Extraction with QO Furfural—

## Increases Cracker Through-Put
## Increases Gasoline Yield
## Lowers Unit Costs
## Improves Products

QO Furfural sharply reduces many trouble-makers encountered in cat cracking. These include the refractory or carbon forming materials that overload the coke burning facilities of the unit and the heavy metal complexes that are notorious catalyst poisoners. Sulfur and nitrogen compounds are reduced substantially. Removal of these materials means increased through-put, increased gasoline yield, lower unit costs, and better product quality.

**Three Uses for One Unit**

One furfural unit can refine lube oil, cycle stock or virgin gas oil as demand dictates. In all three operations, QO furfural offers excellent selectivity, ease of recovery, low cost, ready availability and freedom from excessive toxicity.

**For more complete information, write for our Bulletin 203-A "Physical Data on QO Furfural."**

The Quaker Oats Company
CHEMICALS QO CHEMICALS DEPARTMENT

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**Chicago 54, Illinois**

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**New York 5, N. Y.**

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TUBE-TURN

# *In small piping too you get big savings by welding*

Five years ago, the generally accepted practice among engineers and contractors was to weld non-critical pipe larger than 2-inches and thread the smaller sizes. Today, that dividing line has gone down; much piping as small as ½-inch is now being welded. In small piping as in large, the big reason for welding is *to save money* . . . in installation cost, in material cost, in maintenance cost. See next page for typical results. For the small pipe jobs, too, you get the *most for your money* when you specify and buy TUBE-TURN* Welding Fittings and Flanges. Your nearby Tube Turns' Distributor can give you speedy service in sizes from ½-inch to 42 inches!

*The Leading Manufacturer of Welding Fittings and Flanges*

**TUBE TURNS** LOUISVILLE 1, KENTUCKY

A Division of National Cylinder Gas Company

DISTRICT OFFICES: New York • Philadelphia • Pittsburgh • Cleveland • Detroit • Chicago • Kansas City • Denver
Los Angeles • San Francisco • Seattle • Atlanta • Tulsa • Houston • Dallas • Midland, Texas

*"TUBE-TURN" and "tt" Reg. U.S. Pat. Off.

WHY IT PAYS...

# SMALL DIAMETER PIPING... *why it pays to specify welded construction with* TUBE-TURN *Fittings*

**NEVER LEAKS.** Welded joints are permanently as strong and leakproof as the pipe itself. Photo shows welded lube oil lines for one of four diesel engines, replacing threaded lines which leaked. If welded in first place, would have saved $4000 replacement cost. Pipe is 2½" with TUBE-TURN Fittings.

CUTAWAY SECTION
OF 2" SCHED. 40 PIPE

**SAVES MATERIAL.** Threading cuts half of pipe wall away as shown. The welded joint is as strong as the pipe. An installation of Schedule 40 pipe, welded, is stronger than Schedule 80 threaded. Hence, for equal strength welded piping can cut material costs 30-50%.

**TAKES LESS TIME** to weld than to thread pipe above 2" and about equal time for smaller sizes, according to recent tests on hundreds of joints made by many different pipe fitters. Welded joints in 1½" piping such as the school heating line shown, averaged 7 minutes compared to 8 minutes for threading and tightening fitting.

**IS COMPACT, NEAT.** This installation of 1½" and 2" boiler blow-off piping shows ability to nest welded lines close together for better layout and streamlined appearance. Also, insulation, where needed, is easier to apply.

**TOOLS ARE SIMPLE.** Small, inexpensive welding outfits can cut, weld, heat to bend, solder or braze. They are easy to haul to job and simple to use. All pipe for this factory radiant heating system was fabricated on the site.

**FITTINGS READILY AVAILABLE.** In small sizes, too, your Tube Turns Distributor is stocked to give you prompt, efficient service. Call him on *all* your needs in welding fittings and flanges . . . from ½" to 42".

**MORE INFORMATION**—This bulletin gives helpful information on "The Economics of Welding Small, Noncritical Pipe". Mail the coupon for your free copy.

**TUBE TURNS, Dept. Y-6**
**224 East Broadway, Louisville 1, Kentucky**

Please send free copy of "Economics of Welding Small, Noncritical Pipe".

*Company Name* _____

*Company Address* _____

*City* _____ *Zone* ____ *State* _____

*Your Name* _____

*Position* _____

## Available from your nearby TUBE TURNS' distributor

®"TUBE-TURN" and "tt" Reg. U.S. Pat. Off.

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# TUBE TURNS

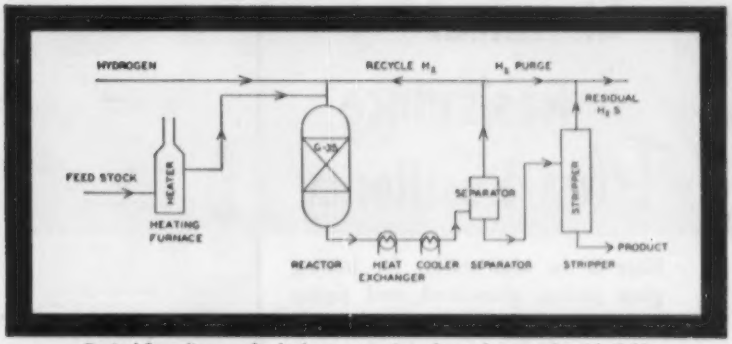
**A DIVISION OF NATIONAL CYLINDER GAS COMPANY**
**LOUISVILLE 1, KENTUCKY**

# NEW GIRDLER CATALYSTS

# G-35

## commercially proven for upgrading petroleum stocks by hydrogen treating

A unit for demonstrating the performance of Girdler G-35 Catalysts on customer feed stocks.




Typical flow diagram for hydrogen treating of petroleum stocks with G-35.

● Naphthas, middle distillates, and gas oils can all be upgraded by hydrogen treating with the use of new Girdler G-35 Catalysts. These highly active cobalt molybdenum catalysts were developed specifically for the desulfurization, denitrification and stabilization of petroleum feed stocks covering a wide molecular range.

Improvement of color, stability, octane rating and burning characteristics and the removal of poisons for catalytic reforming are among the important results achieved.

Girdler G-35 Catalysts feature outstanding physical properties which are retained—even after repeated regenerations and use. Permit outstanding operational flexibility, continuous economical operation with essentially 100% yields.

For detailed information on the new G-35 Catalysts, simply write The Girdler Catalyst Department.

CATALYST DEPARTMENT

**the GIRDLER Company**

A DIVISION OF NATIONAL CYLINDER GAS COMPANY
LOUISVILLE 1, KENTUCKY



For more data on advertised products, use Readers' Service Cards, last page.

MORE OF THE GARLOCK 2,000

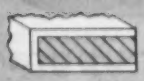
# Teflon*-Jacketed Gaskets for Chemical Resistance Plus Resiliency

Here is the ideal gasket for joining glass piping, glass-lined steel piping and light metal flanges on processing equipment. Teflon-jacketed gaskets with fillers give you resiliency and deformability impossible to obtain with solid Teflon gaskets. Fillers are available of practically any gasketing material for use in each of the four basic designs indicated at the right.

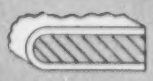
Teflon-jacketed Gaskets are only a part of the Garlock products available in Teflon . . . and only a fraction of the famous "Garlock 2,000", two thousand different styles of packings, gaskets, and seals to meet all your needs. It's the only complete line. It's one reason you get unbiased recommendations from your Garlock representative.

## 4 Basic Designs

1 Slit-center. Teflon is slit from outside diameter to within 1/16" to 1/8" of the inside diameter. Any type filler can be used.



2 Milled-center. Machined from outside diameter. Provides flat surface flush with pipe I.D. reduces impedance to flow.



3 Formed Shield. For large or irregular openings such as elliptical manholes.

4 Double Jacket. Two jackets overlapping to protect both O.D. and I.D. Filler of compressed asbestos between layers of soft woven asbestos commonly used.

*Write for new Catalog AD-154 which describes Garlock Teflon Gaskets and Sheets.*

THE GARLOCK PACKING COMPANY, Palmyra, New York

For Prompt Service, contact one of our 30 sales offices and warehouses throughout the U. S. and Canada.

**DuPont's Trade Mark for its tetrafluoroethylene resin*

GARLOCK

*Packings, Gaskets, Oil Seals, Mechanical Seals, Rubber Expansion Joints*

# The Mail Box . . .

## Good Reference

To The Editor:

I enjoyed the Process Handbook (September PETROLEUM REFINER) as usual and keep it at hand's reach for ready reference. (Now I can discard your Handbook issued in 1954.) The flow diagrams in the 1956 Handbook are easier to read since you have eliminated superfluous heat exchanger lines.

Carol Belton

Cosden Petroleum Corp.
Big Spring, Texas

## OK's Handbook

To The Editor:

Your September issue of the PETROLEUM REFINER I find, on perusal, is up to the usual excellence of your Process Handbook. You are to be complimented on the splendid job done in presenting the outstanding processes available to the refining industry.

Joseph H. Salmon
President, American Development Corp.
New York

## We Help A Reader

To The Editor:

I found great interest in H. M. Thorne's article (July, 1956 PETROLEUM REFINER), "Retort Oil Shale for Chemicals." I would like data on the type of retort and conditions used in retorting oil shale at high temperatures, 1200-1500 F. I also would like to know more about increased octane numbers in gasoline, the effect of adding stabilized tar bases to shale-oil naphtha, and further details re Nos. 2 and 18 of "Literature Cited."

Rinaldo Mauroner

Manova, Italy

*Editor's Note—As Mr. Mauroner knows, we passed his requests on to Author Thorne and the two have been in contact with each other. He is also corresponding with Dr. Clyde Berg, Union Oil Company of California, whose name we furnished.*

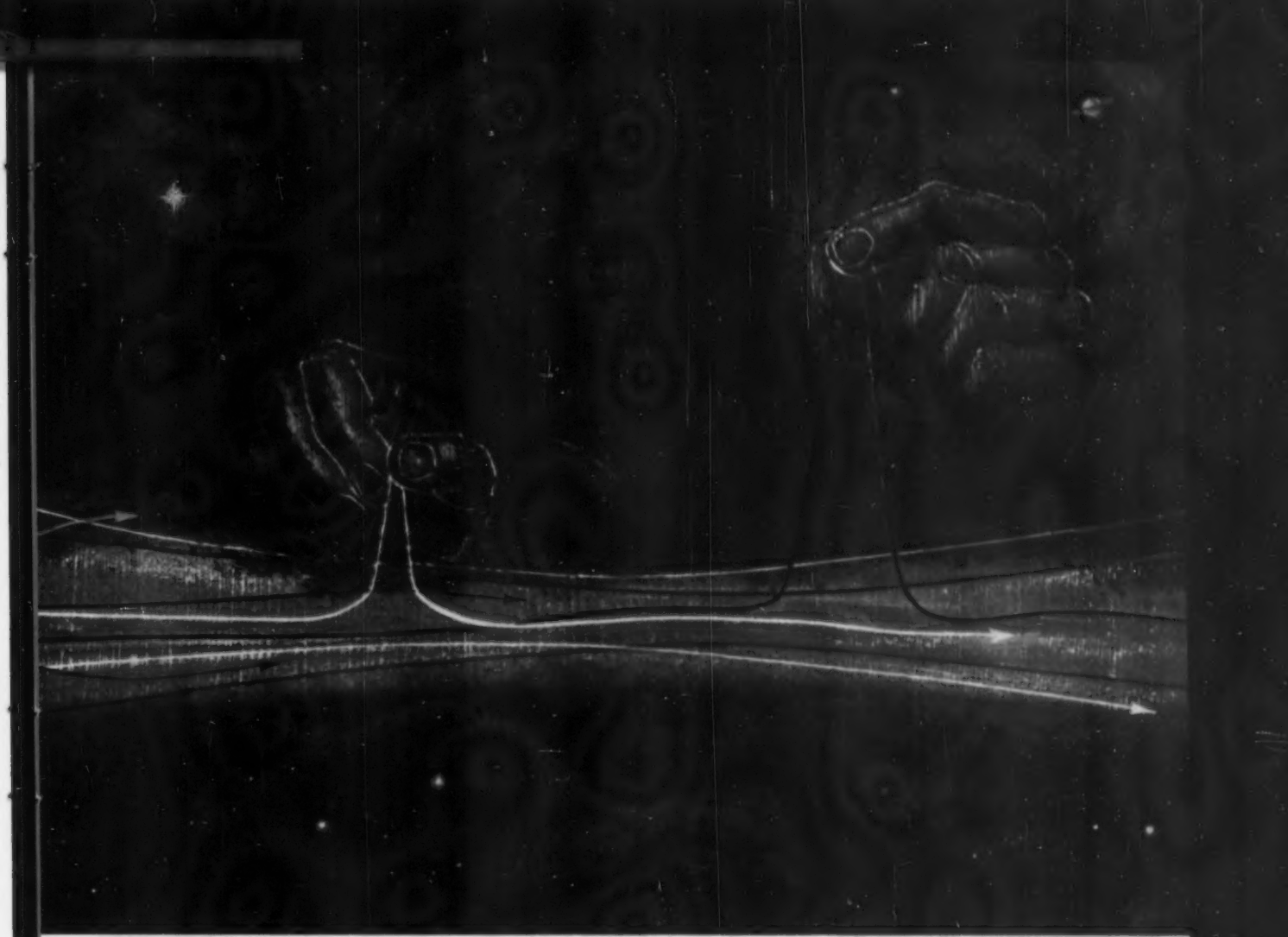
## Polypropylene Service

To The Editor:

I am interested in recent development of polypropylene and also the utilization of propylene. Will you please send information on the current price, manufacturer and their process of polypropylene and also the utilization of propylene in the chemical industry.

Sei Otsuka, D. Sc.
Research Associate
Department of Chemistry
Ohio State University, Columbus

*Editor's Note—Dr. Otsuka, we sent by mail material which had appeared previously in the* PETROLEUM REFINER *and in addition something of our plan to publish shortly a comprehensive article covering the situation in which you indicate specific interest. The name of the only commercial manufacturer of polypropylene and that company's U. S. engineering representative also has been forwarded.*



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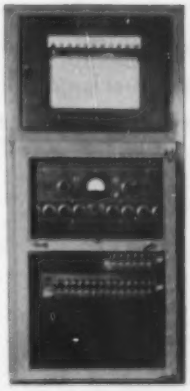
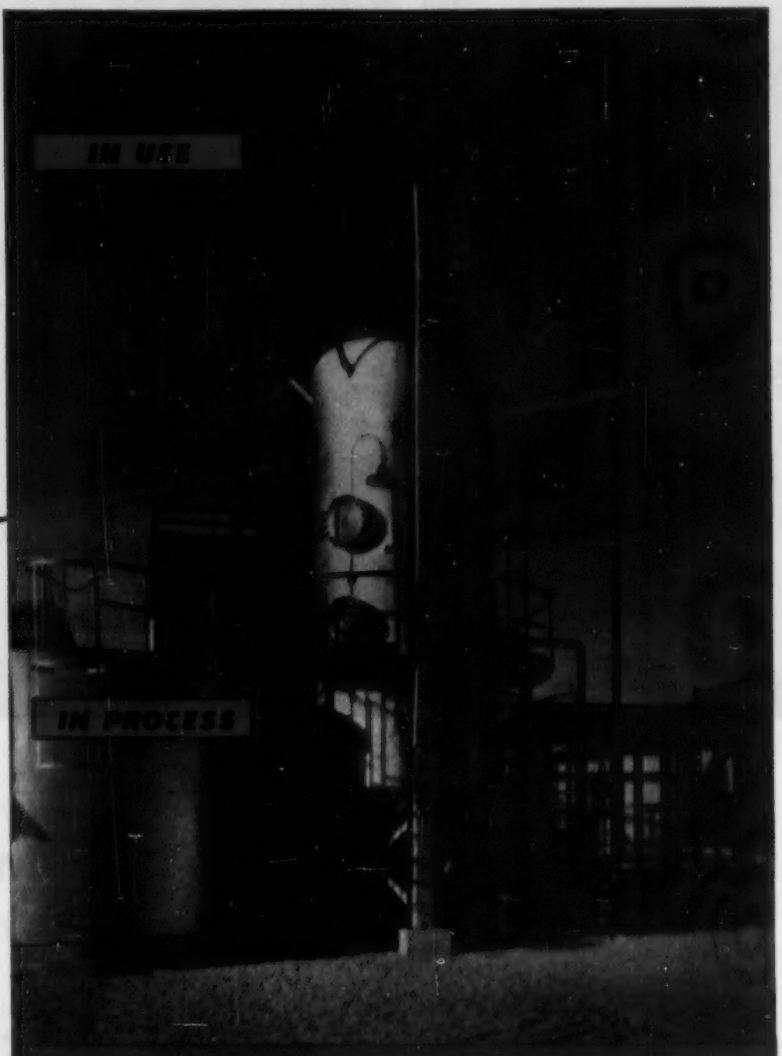


**Beckman** / *process instruments*

# FUEL FOR FLIGHT

*The photo shows a recently-installed Petreco Electrofiner at the Watson Refinery of Richfield Oil Corporation. It is a two stage, 8 foot diameter unit. designed to caustic treat and water wash, or to acid treat and caustic wash. As this photo was made, the Electrofiner was acid treating and caustic washing jet fuels; plainly visible in the sky are jet vapor trails, completing the cycle—from manufacturing process to end use.*

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# A Quick Look at the Industry THIS MONTH

**Refiners Ready to Meet Europe's Crisis . . .**

As smoke screen of confusion begins to settle from Suez impact, two knotty problems remain to harry fuel-thirsty Europe: (1) Tanker shortage and (2) Lack of pipe line capacity to Gulf Coast.

**Here are latest refining developments:**

• **U. S. producers and refiners** say they have more than enough crude and products to meet Europe's immediate demand for 500,000-800,000 bpd.

• **U. S. refiners bid to sell** off record excess of gasoline stocks has bogged at outset. Europe has neither money nor inclination to buy gasoline. It wants fuel oil to keep industries going.

• **What Europe wants, it is beginning to get.** Private U. S. companies, under federal sanction, purchased more than 10 million barrels of crude over normal amounts in Gulf Coast area during November. Purchases of refined products —residuals, distillates and gas-oils—have also been heavy.

• **According to late reports,** Gulf Coast marketers have persuaded a few European purchasers to take some gasoline along with crude and fuel oils. However, amount is small.

—•—

**All Industry Outlook . . .**

Optimism is running high for business boom to continue in '57. Despite Suez crisis, upshoot in wages, increased materials cost and tighter money, U. S. economy will continue to spurt ahead. **Watch for new problems** in keeping growth balanced and in avoiding excesses.

—•—

**Refining Outlook . . .**

Possibly improved. Higher refinery runs on the way. Plans now are to temporarily shift refinery operations to make more fuel oils, less gasoline to keep up with export boom.

**Even so, refiners are keeping wary eye** on ballooning export business. Situation is temporary and return to excess product supply could be in offing at any time.

**Notes on long term supply problem:** Indiana Standard has joined Continental in plea for refiners to take more responsible attitude toward future mountainous inventories. Quote Standard: "Proper balance of supply and demand requires voluntary cutbacks by refiners. Self-restraint is needed and there isn't too much of that in such a competitive industry as oil."

**Refined products prices are improving.** Recent cuts in gasoline prices are being revised upward as inventory position improves. Skyrocketing distillate and residual demands have already created higher fuel oil prices.

—•—

**"Chew More" Campaign for Petrochemicals? . . .**

'56 will see chewing gum industry consuming in excess of $1.28 million worth of polyvinyl acetate and $400,000 worth of microcrystalline waxes—almost $2 million worth of raw materials used in this $165 million industry can be traced directly to petrochemicals.

**"Chew More" and help the** petrochemical industry grow.

## A Quick Look at the Industry (continued)

**Postings on Octane Race . . .**

At least one major is pulling reins on broadcasting its octane ratings. Reason: "It puts us at mercy of liars. If we put out 97 octane gasoline, less responsible marketers can boast 98 octane whether they have it or not—and motorist is in no position to dispute it."

**Volatility requirements of new cars** are becoming critical. Warm up time is longer and could get worse as refiners reduce volatility with higher boiling fractions in making high-octane gasolines. To keep present volatility levels, special light blending components would be needed. Result: Gasoline cost would have to go up.

—•—

**Butylenes from Atomic Radiation . . .**

Atomic radiation promises useable method for converting butanes to butylenes. When commercially feasible, new technique will provide another way to convert gaseous components into gasoline, sans undesirable by-products usually associated with old methods of conversion.

—•—

**API Findings Show Promise . . .**

API pollution experts show much enthusiasm about Silent Sam, powerful infra-red analyzer for detecting components in air. It's in Pasadena, Calif., now; expect to get answers soon as to what air chemicals cause plant damage and eye irritation.

**Two more API projects promise immediate savings** for industry in construction and anlysis. If adopted, standardization of heater tube thickness could save $100,000 in catalytic reformer furnaces alone. Other project is to develop standards for trace metals analysis for use by smaller laboratories—could save half a million dollars a year.

—•—

**New Trend in Upgrading Natural Gasoline? . . .**

Upward climb of octanes leaves natural gasoline behind. Once a valuable component in motor fuel, it is now less important because of its low octane. Latest proposal: Small reformers to be located at the well site and used to upgrade natural gasoline.

—•—

**Maintenance Engineers' Influence Grows . . .**

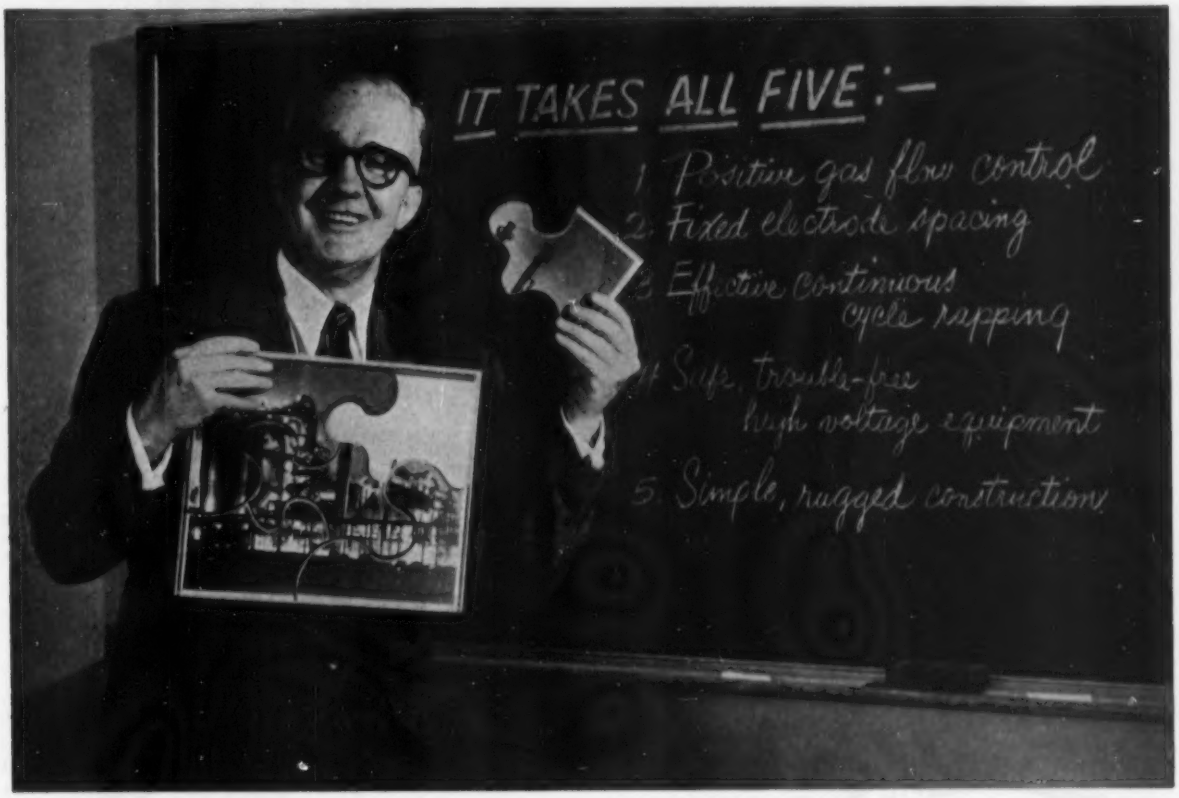
Recent survey shows 66 percent of maintenance engineers have major role in purchase of new equipment and 79 percent influence decision as to what brand to buy. 78 percent of engineers said they are increasing their influence on purchasing—22 percent said influence is same as in the past.

—•—

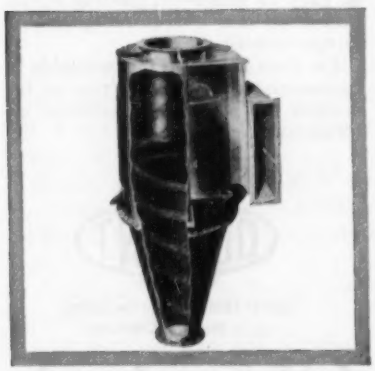
**New Oil Fields . . .**

U. S. wildcatters opened 86 new oil fields during October. Of the better looking ones, six stood out: Discovery by Shell Oil in San Juan County, Utah, with test good for 408 barrels of 42-gravity oil per day. Claiborne Parish, North Louisiana, was site of a good one making 564 barrels of 38-gravity oil. Well drilled by C. M. Roberson. West Texas gained a fair looking pair. One drilled by Seaboard Oil in Dawson County good for 346 barrels of 37-gravity, and another by Stanolind in Gaines County pumping 350 barrels of 38-gravity oil. Monsanto Chemical's new discovery in Kay County, Oklahoma, tested 238 barrels of 42-gravity a day, and Sun found one in Ochiltree County, Texas Panhandle, good for 235 barrels of 39-gravity oil per day.

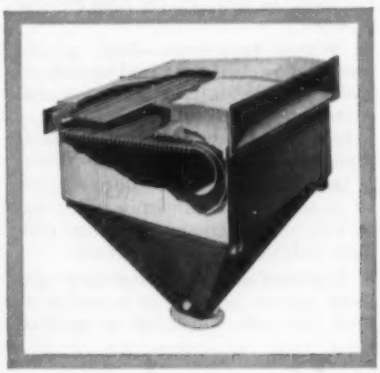
# Buell 'SF' Electric Precipitators meet all 5 basic requirements for TOP EFFICIENCY


IT TAKES ALL FIVE:—
1. Positive gas flow control
2. Fixed electrode spacing
3. Effective continuous cycle rapping
4. Safe, trouble-free high voltage equipment
5. Simple, rugged construction

A slight deficiency of any single factor would be sufficient to impair the performance or service life of any dust recovery system. The constant top efficiency of Buell installations is the result of skillfully adjusting all five elements to best meet various operating conditions . . . provide consistent top efficiency.



*Buell Cyclone Collectors* are noted for their efficiency, too. Here are exclusive reasons why: shave-off design which harnesses back-flow and puts it to work . . . plus extra large diameter design to prevent "plugging."



*Buell "LR" Fly Ash Collectors* are ideal for low and high pressure boiler operations up to 2000 BHP, with either natural or mechanical draft. Check them for high efficiency, simple design, compactness, flexibility in layout.

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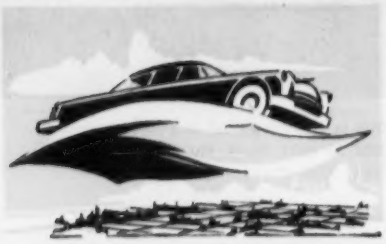
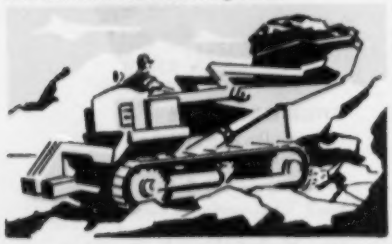
COAL MINE OPERATORS report that heavy-duty mining machinery lasts longer with reduced grease consumption and lower maintenance costs when lubricated with estersil greases.

# Estersil GT offers many advantages to grease users and compounders



AUTOMOTIVE TEST ENGINEERS REPORT the s-m-o-o-t-h, "just-greased" effect lasts longer in cars lubricated with estersil greases.



SAVINGS in downtime and maintenance costs have been experienced by construction companies using estersil greases in heavy-duty equipment.

Du Pont Estersil GT (grease thickener) can help you make a better grease . . . one that has outstanding advantages you can sell.

**1. Excellent shear stability**—Even under severe high-shear, high-temperature operating conditions, greases made with estersil GT show excellent resistance to thinning for long periods of time.

**2. Water resistance**—Each minute estersil particle is protected by a chemical "raincoat." This gives estersil greases built-in water resistance . . . helps eliminate the danger of washout even under drastic water conditions.

**3. Unusual thermal stability**—Estersil greases are nonmelting. Even extremely wide temperature ranges produce little change in consistency.

**4. Superior oxidation stability**—Estersil greases are almost as stable as their base oils and need no antioxidants under most service conditions.

**5. Superior handling qualities**—Greases thickened with estersil GT can be *more easily handled* in almost any application. This is because their unusually satisfactory thermal and mechanical stability permits use of a much softer grease.

**6. Easy to make**—A milling operation is all that is required to manufacture estersil greases.

Du Pont Estersil GT is available in commercial quantities. Write us for samples and additional technical information.

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# Oil Cannot Speak - - - But YOU Can

IF OIL COULD SPEAK it would have many fascinating truths to tell the non-oil public—truths that would win thousands of new friends for the oil industry.

But, oil can't speak—you can. You, as an individual, can win many new friends for the oil industry, if you will pass the true facts on to your non-oil industry friends.

This article—the first in a series—is being presented for one purpose: To equip you with as many facts as possible about your industry, so you can tell the story that oil is unable to relate.

Read these facts. You will find them informative—and interesting.

EVERY OIL WORKER, from field man or secretary to chairman of the board has a stake in the public's attitude toward the oil industry.

If the attitude is bad, then the worker's chances of a better job in the future are bad. If the attitude is good, then his chances are good.

What can create a better public attitude?

The truth, nothing but the truth.

The average John Q. Public, the voter, your friend who isn't in the oil industry, is daily being fed misrepresentations by somebody outside the oil industry. Occasionally somebody in the oil industry makes a bad bobble and the nation's press plays it to the hilt—with bad results to you and your job.

The truth is enough. If you can pass a few truths on to your friends who live next door, but are not in the oil industry, or whom you go to visit at night or who visit you—*that* is *your* part of a campaign for better understanding.

That is all any of us in the oil industry can expect—a better understanding—that is all *you* can do, help, among your friends, to create better understanding.

For instance there is the neighbor who thinks that oil men have a happy knack of going out and drilling a wildcat well—with consequent riches. *You* know better. There is the bridge (or poker) partner who thinks three or four large companies refine all the nation's oil. *You* know better.

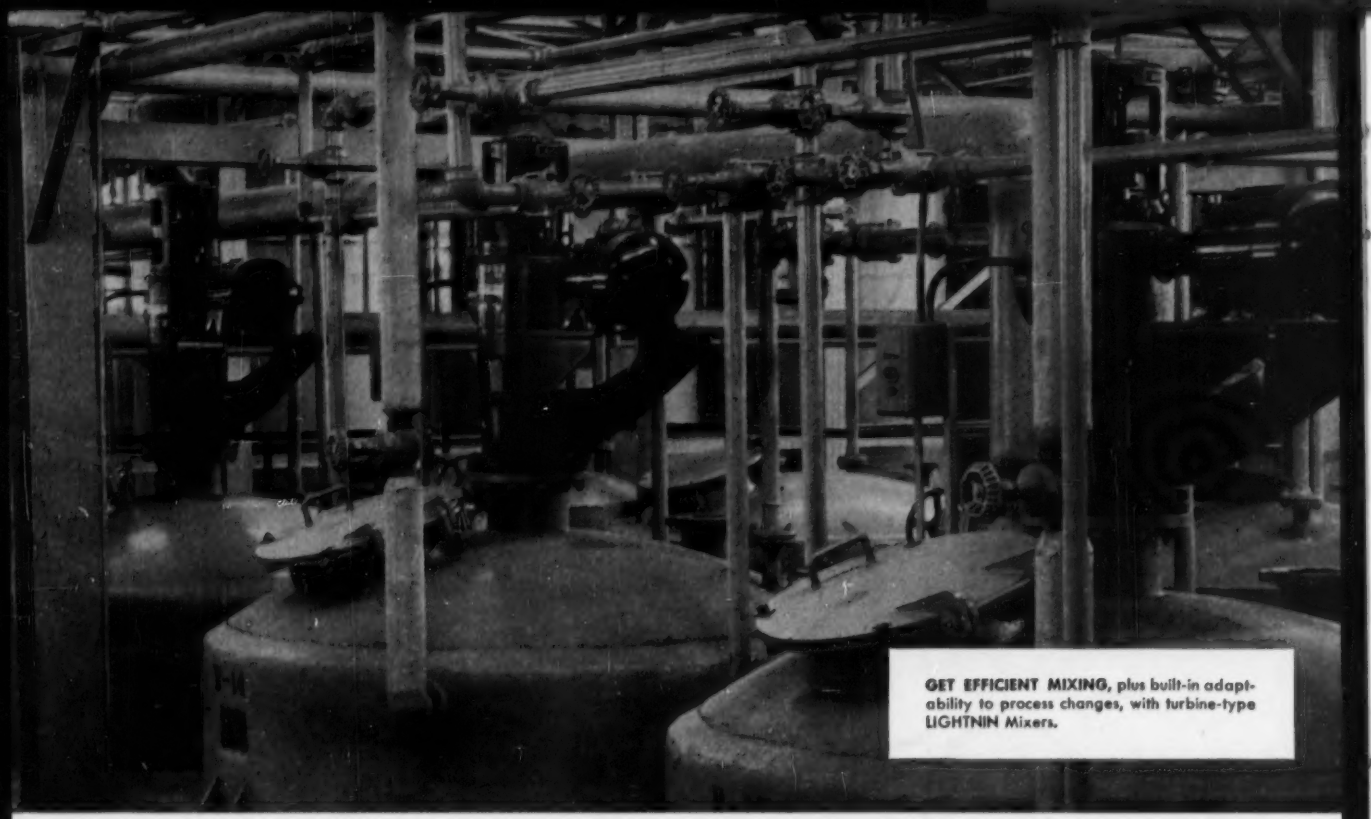
How, specifically, can you help?

PETROLEUM REFINER has, with the help of reputable industry sources, compiled some pertinent *facts* you can pass on. Below you will find some of them. Future issues will contain more facts under the heading—"If Oil Could Speak."

Look for these facts—use them. Chances are you will find them very interesting to yourself—and we think your non-oil friends will be interested in hearing them from you.

**If oil could speak it would tell the world these facts:**

• One out of every 38 workers in the U. S. is employedin the oil industry. The million-plus oil employes are paid



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# *Use this* **proved method** *to get good fluid mixing*

You can't afford to *guess* about fluid mixing. And you don't need to.

On any mixing operation you can get factual answers to questions like these, to guide you in your mixer selection:

1. What precise balance of *fluid flow* and *fluid shear* will do my mixing job best?
2. If this balance can be attained in different ways, what is the *most efficient* and economical way?
3. In scaling-up, does power required per unit volume remain constant? If not, by what factor does it increase or decrease?
4. Will the mixer transmit the required power to the mix, and do it efficiently?
5. Can the mixer be installed without special construction? Can I get standard replacement parts quickly if I ever need them?
6. Am I protected against mixer obsolescence in case of a process change?

You *know* the answers to these vital questions, when you mix with LIGHTNIN Mixers.

### Predicting results

Even on the simplest mixer application, your LIGHTNIN sales engineer's recommendation is based on thousands of pilot runs, plus years of in-the-field experience.

On complex mixing jobs, pilot runs at MIXCO quickly find the impeller-to-tank diameter ratio and input power that will produce the optimum fluid regime most economically. Scale-up is *guaranteed accurate.*

### Mechanical economy

Your mixer investment goes into equipment that is mechanically up-to-the-minute. Hundreds of *standard* LIGHTNIN power-speed combinations (interchangeable in many models); widest possible choice of in-stock materials and interchangeable components, give you assurance of correct application, smooth running, and flexibility when you need it.

For fluid mixing that does what you want it to do, call in your LIGHTNIN Mixer representative. (He's listed in Refinery Catalog.) Or write us direct.

**GET LOWEST-COST MIXING,** gasoline blending, suspension of BS&W in crude, with LIGHTNIN Side Entering Mixers. New rotary mechanical shaft seal ends stuffing-box repacking forever; stops leakage; runs for years without adjustment. Yet you can replace it in minutes if ever necessary.

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- ☐ B-104 Side entering: 1 to 25 HP
- ☐ B-112 Laboratory and small-batch production types
- ☐ B-109 Condensed catalog showing all types
- ☐ B-111 Quick-change rotary mechanical seals for pressure and vacuum mixing
- ☐ B-107 Data sheet for figuring mixer requirements

Check, clip, and mail with your name, title, company address to:

**MIXING EQUIPMENT Co., Inc., 164-n Mt. Read Blvd., Rochester 11, N. Y.**

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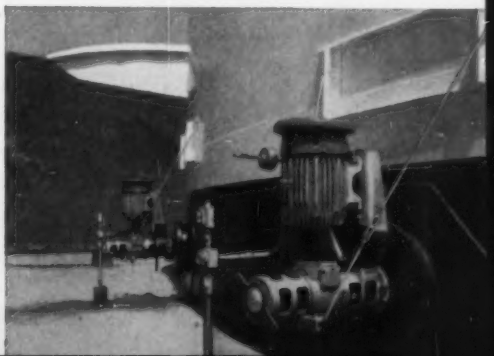

the second highest wages in the nation.

- Thirty of the larger oil companies have been forced to borrow over $5 billion in the past 20 years, despite assertions from various sources that the 27½ percent depletion provision is excessive.
- Eighty percent of all oil consumed in World War II came from U. S. wells!
- The average Texas oil well produces 20 barrels a day, compared with a national average of 14 barrels a day. The average well in the Persian Gulf produces 5000 barrels of oil a day.
- Within 25 years total demand for oil products has nearly tripled—from 3 million barrels a day to well over 8 million barrels a day. The oil industry has met this tremendous growth in demand—and to spare!
- Despite a tremendous consumption of over 41 billion barrels of oil since 1926, the known reserves are higher today than at any time in U. S. history.
- Since World War II, the capacity of refineries in the U. S. has increased 60 percent. This growth has met the tremendous challenge of the rapidly expanding needs of the postwar economy—and it has, at the request of the government, provided a cushion of reserve capacity that could be drawn on in times of emergency.

**Remember: Oil can't speak—you can. Only you can give non-oil people the true facts about your oil industry.**

## Europe Needs U. S. Oils

WITH THE closing of the Suez Canal, Western Europe looks to the U. S. for a large portion of its needed oil. It is fortunate that this nation has the ability to fill this need, but it is unfortunate that Europe does not need, nor can afford, what the U. S. could best furnish, gasoline. With the nation's motor fuel stocks causing considerable concern because of their magnitude, it would be a blessing if some of this supply could be taken off its hands. But, gasoline comprises a relatively small part of Europe's oil needs, and even this has been cut substantially by gasoline rationing.

Crude and fuel oils are the items of greatest demand in Europe. Although U. S. crude inventories were high and in good shape for draining off, they were not located too well geographically. Enough pipe lines to move crude to coastal ports and tankships to take it from there are not immediately available. Fuel oils were caught in good supply for domestic demands, but they are nowhere near exeecssive and not heavy enough for great amounts of export.

It seems that crude should be the prime movement to Europe, as its refineries are designed to emphasize fuel oil output. If U. S. plants are called upon to supply this nation and Europe with fuel oils, somebody will have to come up with a bright idea as to what can be done with the resulting gasoline.

## Chemistry and Diplomacy

THE RUSTLE OF the press continues about new processes and chemical developments for making "natural" synthetic rubber. All of this seems to be aimed at absolute independence from overseas natural rubber supplies.

Could it be that our scientists have the better idea and can do a better job with chemistry than our statesmen can do with diplomacy? However you would answer that question, it seems to us that science never should be substituted for diplomatic negotiations and peaceful existence throughout the world. We must learn to live together.

No one should advocate discontinuance of scientific research in any field, much less rubber. However, we do vote for less unfavorable publicity regarding these discoveries—more of the "announcement" type of news release. These announcements, in their subtle way, really tell the world that we have another "out" if anyone attempts to put the squeeze on us. This type of research will, in the end, smooth the road for our diplomats to negotiate fair and equitable trade agreements.

Science has demonstrated its ability to produce, particularly under pressure, by developing outstanding men in all fields. These true scientists really have a feel for the world and will devote their efforts to the betterment of all if not overly directed by the diplomats.

In order for the growing population to become better housed, better clothed, and better fed as well as to enjoy higher standards of living, science in all fields will be called upon to produce greater "wonders" than ever before.

The future of our civilization depends upon the widespread adoption of the scientific habit of mind. Our educational systems must discover how to mature and make effective this scientific habit.

We'll admit that people are more complex than even the most dastardly chemical reaction ever dreamed-up. However, most technical problems are solved by breaking them up into small workable sections. Perhaps our diplomats can find a lesson here.

*I place economy among the first and most important virtues, and public debt as the greatest of dangers. We must make our choice between economy and liberty or profusion and servitude.* —Thomas Jefferson

---

*When wisely conceived, intelligently directed and generously supported, research yields returns of an order of value all out of proportion to its cost. It becomes the mainspring of progress.*

—Arthur Dehon Little

# Tracing the path of fuel with carbon-14

*Ethyl Research tags 1 in 100,000,000 atoms with radioactive carbon for a better picture of distribution in the cylinders.*

**by D. E. COOPER**

***Ethyl Corporation, Detroit, Mich.***

The distribution of fuel components and fuel additives to the cylinders of multicylinder engines is of prime importance to the petroleum industry. Just as a chain is only as strong as its weakest link, so is an engine's performance limited by the one cylinder which does not continuously get its proper dosage of high-octane hydrocarbons or of tetraethyllead.

The goal of engine designers is the creation of an engine wherein the fuel/air ratio, hydrocarbon composition and additive concentrations are identical for each cylinder of a multicylinder engine. Fuel injection—now becoming commercially available—represents one approach to the solution of this difficult problem.

Whether fuel injection or carburetion is employed, however, an accurate knowledge of fuel and additive distribution in engines is necessary to assure optimum use of the gasolines the refiner is producing today.

### A continuing study

As is the case with most of Ethyl's other basic research studies, the study of fuel distribution has been a continuing one. Some years ago, a glass manifold was installed on an engine and motion pictures were made of flow patterns, giving some insight into the quantities of fuel mixture fed to various cylinders.

A second step in Ethyl fuel distribution studies involved the tagging of specific hydrocarbons with deuterium or heavy hydrogen. One component (the cyclopentanes, for example) had a specific number of hydrogen atoms replaced with heavy hydrogen. This special fuel was then burned in the engine. Samples of the exhaust gases from various cylinders were condensed and analyzed in a mass spectrometer to give a picture of the distribution of that particular

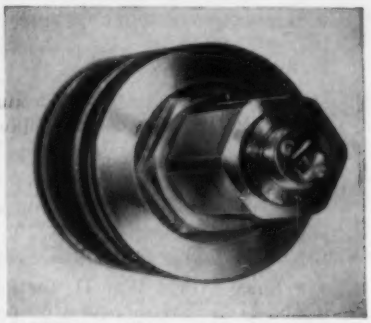

**FIGURE 1.** Nose view of combined sampling valve and spark plug.

**FIGURE 2.** Test engine in the laboratory and gas sampling and collecting system.

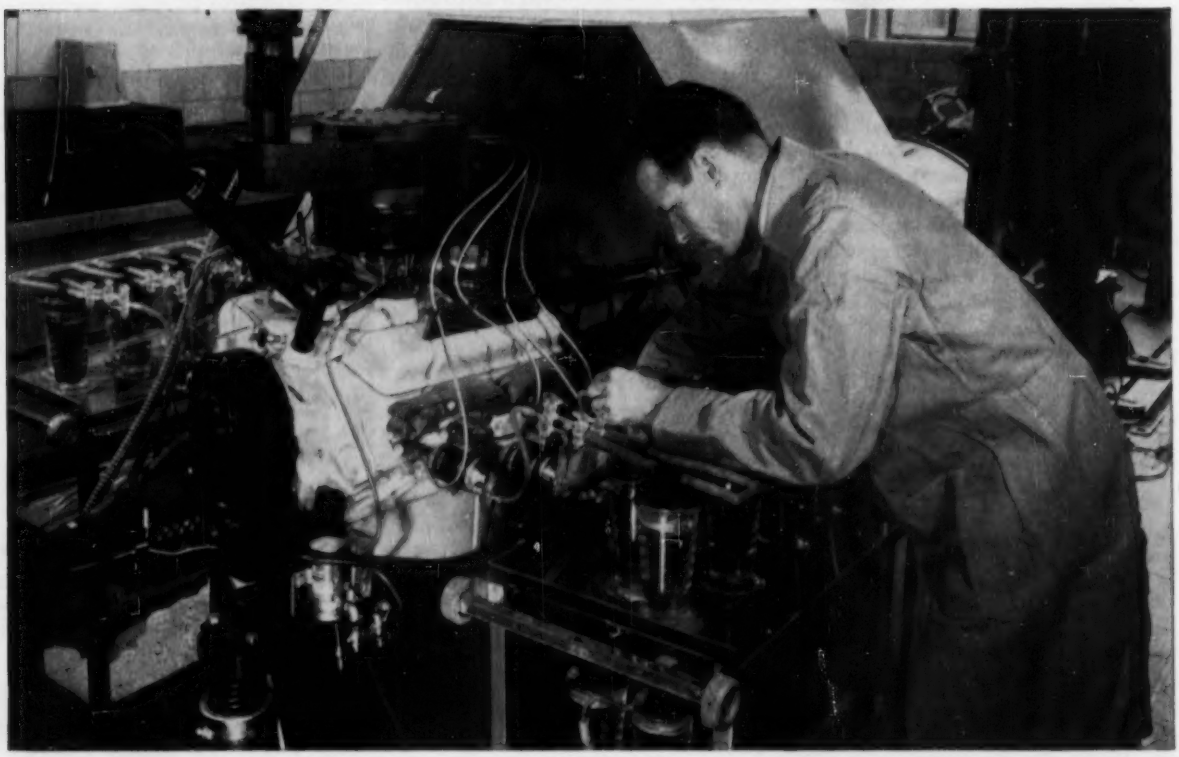

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**FIGURE 3.** Scintillation counter setup at Ethyl Research Laboratories for examining tritium-containing condensate samples.

hydrocarbon among the cylinders of the engine on test. This technique required, however, that the ratio of heavy hydrogen to normal hydrogen be at least 1 to 100 and thus ruled out studies of additive concentrations, which are much smaller.

### Tagged carbon atoms

A third step in this continuing program of fuel distribution studies has involved switching from a stable isotope such as deuterium to a radioactive one such as carbon-14. Now it becomes possible to tag tetraethyllead with carbon-14 and measure its concentration in an engine cylinder accurately, even though only one tagged atom is present among 100,000,000 normal carbon-12 atoms!

All of these distribution studies involved the use of a quick-opening (1/1,000 second) sampling valve. This valve samples the contents of a particular cylinder. It is screwed into the spark-plug opening and combines the sampling valve with spark-plug electrodes. Figure 1 shows a nose view of this combined sampling valve and spark plug.

Figure 2 shows the test engine in the laboratory and the gas sampling and collecting system. The gas samples are bubbled through absorbing solutions of barium hydroxide. The carbon dioxide is regenerated and transferred to an ionization chamber, where its beta activity is measured by a vibrating-reed electrometer.

### And now . . . tritium

The newest refinement in this study consists of the replacement of carbon-14 with hydrogen-3 or tritium as the radioactive tracer element. The use of tritium simplifies and makes less expensive the preparation of tagged hydrocarbon or additive molecules for study. It also simplifies the exhaust-gas-sample collection technique. The scintillation counter used for studying the tritium-containing condensate samples from the cylinders is shown in Figure 3.

**As is the case with all of our basic research studies, the information from this continuing study of fuel distribution is available to the petroleum industry. We would be happy to discuss any particular aspect of this problem with you in your office. We would also be happy to have you visit our Detroit Laboratories to see this equipment and discuss it with our technical personnel. In either case, contact your local Ethyl representative for an appointment.**


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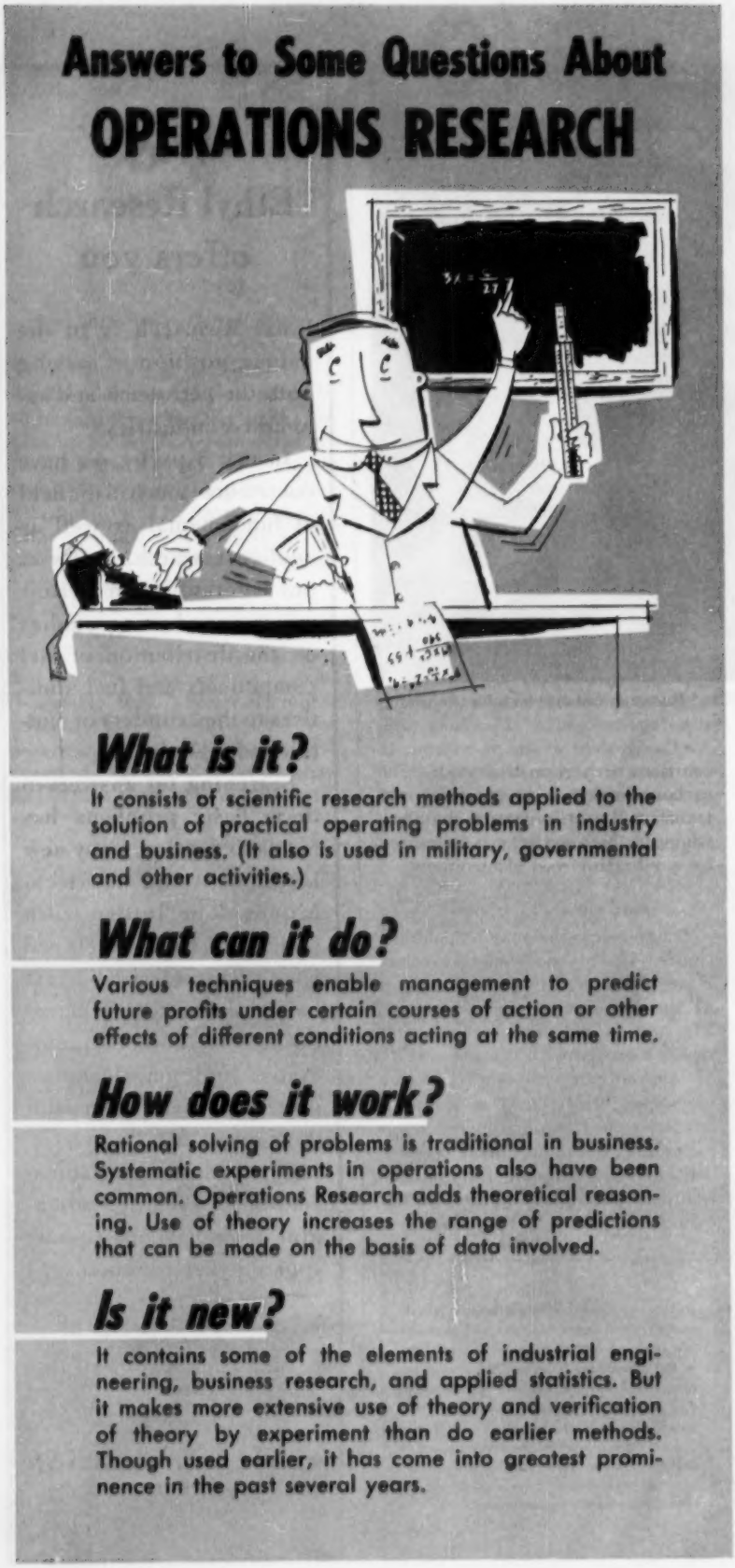
# How


Answers to Some Questions About
OPERATIONS RESEARCH
What is it?
It consists of scientific research methods applied to the solution of practical operating problems in industry and business. (It also is used in military, governmental and other activities.)
What can it do?
Various techniques enable management to predict future profits under certain courses of action or other effects of different conditions acting at the same time.
How does it work?
Rational solving of problems is traditional in business. Systematic experiments in operations also have been common. Operations Research adds theoretical reasoning. Use of theory increases the range of predictions that can be made on the basis of data involved.
Is it new?
It contains some of the elements of industrial engineering, business research, and applied statistics. But it makes more extensive use of theory and verification of theory by experiment than do earlier methods. Though used earlier, it has come into greatest prominence in the past several years.

**Tage A. Mortensen**
Midwest Research Institute
Kansas City, Missouri

ALMOST EVERYONE has heard of operations research—OR—and seen it labeled as a new management tool. Some companies were using it, or elements of it, before the term was coined. It has, at times, been presented as a magic formula, a wonder drug, effecting near-fabulous improvements in company operations. So, alert management will ask: How does it work and what can it do? What does it cost? Is it basically different from other management services? And how do we go about using it?

These questions have been pondered in technical papers, seminars and symposia during the last few years, and the host of answers given has covered quite a bit of territory. They have sometimes been contradictory answers. This is to be expected; the questions have been general, and hence difficult to answer without undue use of *if's* and *but's*. Questions also have been philosophical, leaving room for many different (but equally true) formulations of answers.

But a fairly solid description has emerged of the main characteristics of operations research. A suitable definition may be that **operations research is the use of the scientific methods, as it is developed by the physical sciences, on a new subject, operations.** Whereas earlier research has been done on things, OR is research on *what is done with things.*

That research methods of the physical sciences are potent ones cannot be disputed; they have been a prime

# Operations Research Aids the Refiner

**Refinery management is making excellent use of operations research in business and industrial operations.**

factor in the tremendous advances in our technology. The question of whether these methods will be equally applicable to business and industrial operations is therefore well worth considering.

**Philosophy and Principles.** Main object of physical research is explanation of events in simpler terms. The basic tenet behind this is that there exists a cause-and-effect relationship, so that the same cause will, under equal conditions, always produce the same effect. The researcher strives to express the basic cause-and-effect relationships numerically in terms of general laws which may be used to determine the combined effect when several causes act simultaneously, and to predict the course of future events of similar types.

Policy for this research is dominated by two elements which continually interplay: *experiment* and *theory*. With most persons favoring practical views rather than abstract reasoning, beginning of an investigation is most often experimental; that is, producing, repeating and observing events in question under controlled conditions and classifying the outcome. It produces reliable, but spotty, information within a limited set of boundaries (depending on how extensive the experimental series is). Possibilities for erratic behavior exist, of course, even within the test limits, and the experiment by itself is of modest value for predictions outside these limits.

Enter here theory. To begin with, it is tentative, it is a hypothesis which is accepted until contradicted. It is an abstract formulation, expressible in mathematical equations, of the laws thought to govern events in question.

The scientist will immediately set up experiments in which he will make conditions as embarrassing and awkward as possible for his new hypothesis by making the experiments cover the most extreme cases. More often than not this will uncover weaknesses in the hypothesis, and the scientist will modify it until agreement is reached between experiment and hypothesis. He will then start over again on a new cycle for further refinements.

Somewhere during this work, the hypothesis will have matured into a theory which can be accepted as proven and substantiated over a very large range of conditions. Thus, by enlisting the services of theory, the value of the spotty experimental knowledge has been increased many fold. Predictions in the form of interpolations and extrapolations from the data can be made without fear of loopholes in the formulated general laws. This must be emphasized. Although the experimental and empirical part of an investigation is the one which is most easily followed and understood, it is the theoretical and abstract part which multiplies the range of application of the data, and which guards against unexpected kinks in the behavior of the things investigated.

In business and industry, rational solving of problems has been used as long as business itself has existed. Systematic experiments on operations have been made. However, additional use of theoretical reasoning—or, to employ a fashionable term, of *mathematical models*—is one of the characteristics of operations research.

Admittedly, this thrust of theoretical tools into business problems will not be as extensive as in the physical sciences; too many factors (such as human behavior) are beyond analytical and numerical formulation. Yet, mathematical models have had enough startlingly successful applications to operations to spark continued efforts for further use.

Once the model has been established, it is used for *dry runs*, giving readily different consequences of various actions or strategies; the consequences in this case meaning profit, return on investment, or whatever yardstick is being used in the model. Thus it furnishes information to aid management in reaching decisions concerning these actions—the management decisions being the causes, the model showing the effect—to the extent that the significant variables can be drawn into the analysis. This has contributed to a very important aspect of operations research: *its broadness of view*.

An OR study may be confined initially to one department of a company, but by its very nature, it will point out significant causes located in other departments of the company, if any. And so, quite often, a study will eventually be carried out on a higher level than when originally formulated, and its scope will be company-wide rather than department-wide.

If it is agreed that OR tends to give, as fully as possible, a picture of the consequences of various business strategies and a ranking of them, and if it is agreed that the viewpoint of OR is company-wide, one may ask: Will operations research tend to replace management? The answer is no, it will not.

Questions of psychology, morale,

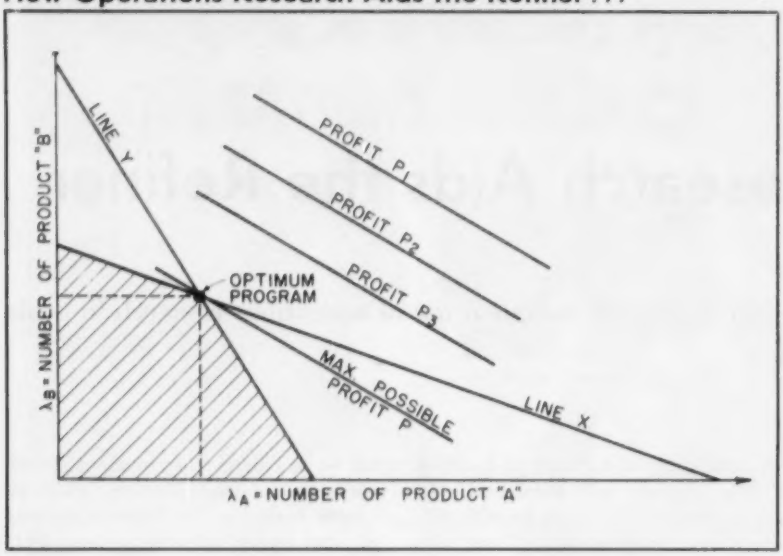



***Figure 1—A production problem solved by a graphical method . . .***

**A manufacturer has limited supplies of two raw materials. He is making two products. His problem: How many of each should he make to get maximum profit and still be within limits of the raw materials? The answer is indicated at the point (large dot) labeled "Optimum Program." The theoretical reasoning or mathematical model here employed is linear programming. Mathematical computations increase the range of predictions that can be made on the basis of the data involved. This is a relatively simple problem. Similar solutions are possible for much more complex problems, involving many more variables.**

politics and ethics enter into all significant business decisions. These factors probably will always be outside and above any mathematical formulation of a problem. Yet they must be considered before management can possibly make sound decisions.

What operations research can do is to recognize and solve problems of a routine or repetitive nature. Its causality basis implies repetition. And the often extensive effort required in applying OR techniques makes it feasible to use the method only when the repetitive nature of the problem warrants such an initial effort.

Hence, OR should be considered a means of eliminating drudgery of routine decisions, leaving management free to cope with those situations which require experience, intuition and leadership for their solution, a means for leaving management free to manage.

**Methods and techniques.** The foregoing has concerned the general philosophy and principles of operations research. Technical literature gives extensive coverage of this subject[4-1], as well as that of techniques and methods.

Now take a closer look at the use of mathematical models and the ingredients from which they are made. One of these is linear programming,[5, 6] a technique which can determine the best solution to allocation problems where a number of processes (for example production or promotion activities) are competing for limited amounts of various resources (for example raw materials, machine tool time, or capital), provided all relationships are linear combinations.

Consider the following illustration: A manufacturer has two products, A and B. They are produced from the raw materials X and Y, which enter into A and B in different amounts per item produced. Total resources of X and Y are limited. The manufacturer may ask for a production program, that is, how many items A and how many items B he should produce to make a maximum net profit and, of course, still be within the raw material limits.

Let:

$\lambda_A$ be the number produced of product A

$\lambda_B$ be the number produced of product B

$a_{XA}$ be the amount of resource X going into each item of product A

$a_{XB}$ be the amount of resource X going into each item of product B

$a_{YA}$ be the amount of resource Y going into each item of product A

$a_{YB}$ be the amount of resource Y going into each item of product B

$c_A$ be the net profit on each item of product A

$c_B$ be the net profit on each item of product B

$b_X$ be the maximum amount of resource X available

$b_Y$ be the maximum amount of resource Y available

The unknown numbers $\lambda_A$ and $\lambda_B$ are to be determined so that the profits P are maximized. This may be written as

$$P = \lambda_A \cdot c_A + \lambda_B \cdot c_B = \text{maximum} \quad (1)$$

The limitations are

$$\lambda_A \cdot a_{XA} + \lambda_B \cdot a_{XB} \leqq b_X \quad (2)$$

and

$$\lambda_A \cdot a_{YA} + \lambda_B \cdot a_{YB} \leqq b_Y \quad (3)$$

In the first of these inequalities, the left side represents the amount of raw material X which is used, consisting of $\lambda_A \cdot a_{XA}$ into product A and $\lambda_B \cdot a_{XB}$ going into product B. This, of course, must not exceed the amount $b_X$ available.

Similarly, the left side of the second inequality represents the amounts of resource Y going into products A and B. This must not exceed the amount $b_Y$ available.

Further, since the manufacturer cannot produce a negative number of items A and B:

$$\lambda_A \geqq 0$$
$$\lambda_B \geqq 0 \quad (4)$$

The above is a standard formulation of a linear program, in this case in two dimensions.

This case can be solved readily by graphical methods, as illustrated by Figure 1. The figure represents the first quadrant in the $\lambda_A$-$\lambda_B$-plane. Thus each point represents a certain manufacturing program.

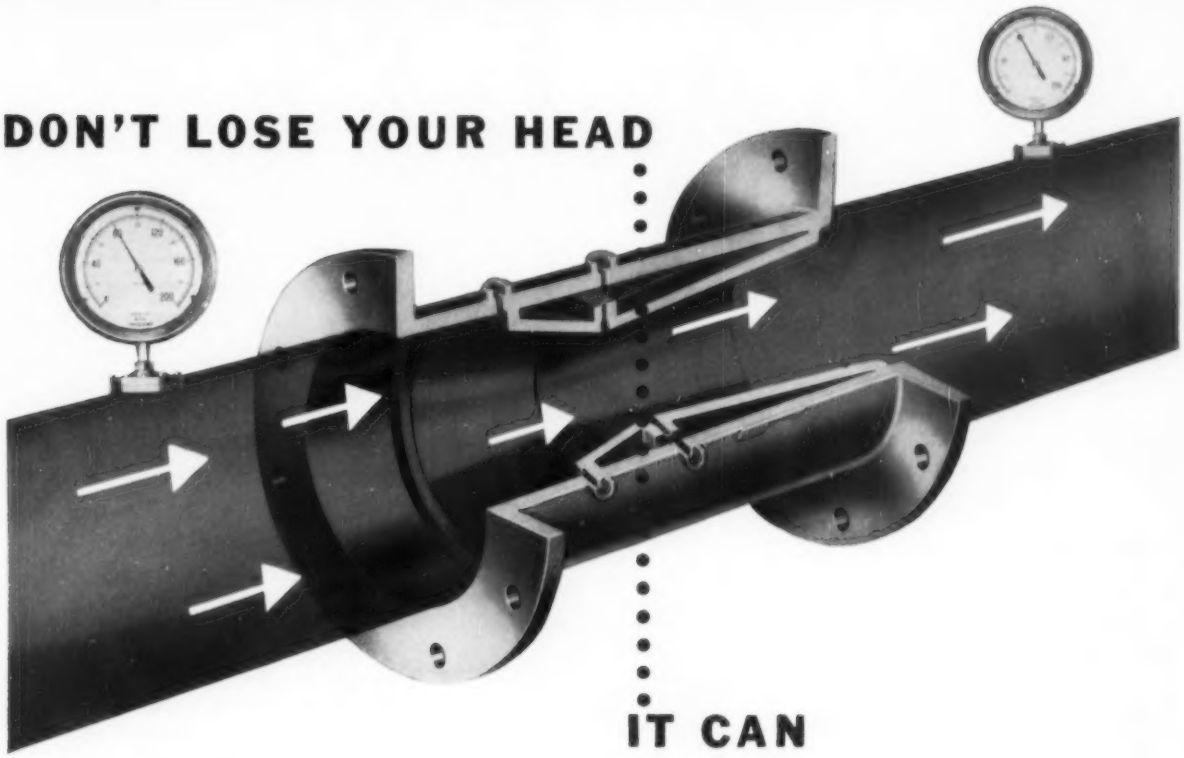
If the less-than sign in inequality (2) is omitted, there results an equation which may be represented by the line X on Figure 1. All points satisfying inequality (2) must therefore lie below the line X. Similarly, all points satisfying inequality (3) must lie below or on a certain line, drawn as line Y in the diagram.

All points (representing all manufacturing programs) satisfying simultaneously requirements (2), (3), and

***Continued on Page 270***

# 1956 Petrochemical Developments Issue

## DON'T LOSE YOUR HEAD



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*Now*, the use of the kinetic energy of steam principle gives us a modern type of steam trap.

The Sarco TD obsoletes all other types for most 10 to 600 psi installations. For example, it operates without a valve closing device—no bucket, float, bellows, pins, levers or gaskets.

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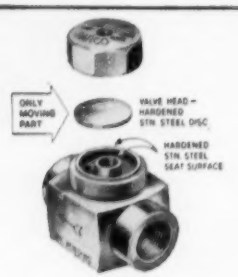
*For a trial installation—write today.*



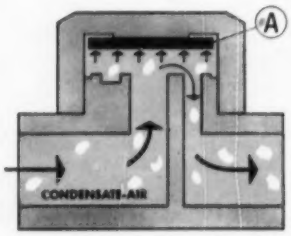

**Only 3 parts...all stainless steel**

Sizes ⅜ to 1"—each body is as small as a tee fitting! Capacity is determined not by a bulky body but by the effective orifice, valve action, pressure drop and condensate temperature.

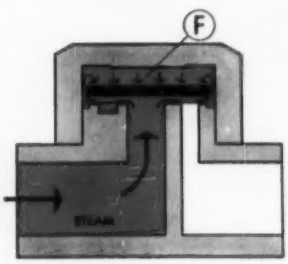
### Many Advantages

1. *Practically no maintenance*—no valve mechanism, no narrow channels. Trouble-free simple design. Only 3 parts—all stainless steel.
2. *One trap for all pressures*—self-adjusting. One large capacity seat for 600 psi as for 10 psi. No changes or adjustments.
3. *Operates equally well on all loads*—on heavy, light or no condensate load. No prime to lose. No adjustments.
4. *No steam leak required*—to operate the Sarco TD. Closes tight against steam.
5. *Discharges at steam temperature and vents air* and air-steam mixtures at start-up and during operation.
6. *Freeze-proof*—when installed with outlet down, free to drain.

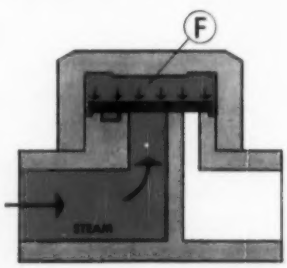
**Only Sarco TD Thermodynamic Steam Trap Uses This Unique Operating Principle Which Permits Trouble-Free TD Design**




**1.** Inlet pressure raises disc "A" from seat... immediate discharge of air and condensate at steam temperature.




**2.** Steam follows the condensate and the high velocity jet across the bottom of disc "A" creates a low pressure area (Bernoulli effect)...the jet is deflected into chamber "F" where it builds up pressure by recompression and this pressure acts on the top of the disc "A"...




**3.** Pressure in chamber "F", acting on full top area of disc "A", exceeds force of incoming steam and low pressure area under the disc...and immediately forces it down, closing the inlet. As condensation decreases the pressure in chamber "F", the disc rises and steps 1 or 2 repeat.

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**OUR INDUSTRIAL ADVISORS** for this 1956 Petrochemical Issue are shown above, left to right: R. L. Mitchell, Celanese Corporation of America; James Kirk, Continental Oil Company; A. G. Oblad, Houdry Process Corporation; Lewis F. Hatch, University of Texas; Frank J. Soday, Chemstrand Corporation, and Jack Sherred, Lion Oil Company. These experts pointed out important developments and guided us in our search for material included in this issue*

# Petrochemical Developments—1956

THE PETROCHEMICAL INDUSTRY is continuing its explosive growth. At the present time petrochemicals account for over 25 percent of all chemical production. In fact 35 BILLION pounds of petrochemical products are valued in excess of $3 BILLION. This is big business! And yet, the raw materials for this fabulous industry are equivalent to only about two percent of the entire crude oil production.

Did you know that the capital expenditures for new petrochemical plants and revisions to old ones were over $570 MILLION in 1956? This compares favorably with $765 MILLION for the refining industry in 1956. BUT . . . in 1957 the planned expansions for this petrochemical industry is expected to go over $700 MILLION. All of this is planned by only 200 companies operating over 360 petrochemical plants.

**The Petroleum REFINER** continues to lead the field in bringing you up to date on the advances in processes, technical know-hows, market developments, and engineering related to this dynamic industry. In this fourth annual Petrochemical Issue we bring you the most important new developments in this industry by the leading authorities of the industry.

The most important processing developments are Superfraction (page 179) and Low Temperature Separation (page 201). Articles covering these new processing tools serve to keep you abreast of the changing times.

**Increasing capacity** with a minimum of capital investment (page 169) and new manufacturing processes (page 172) point out ways to strengthen the profit margin in your plant. Another new idea is the design and engineering of new plants with the "Marketing Concept" in mind (page 187) to insure against obsolescence of process and equipment.

Important new outlets for petrochemicals (page 145) as well as new uses for petrochemical intermediates (page 157) can help the industry grow and prosper. A comparison of the process economics of several processes (page 191) can help you in your decision on the route your company should take.

Petrochemicals have reached a state of "adulthood" that is very healthy. The coming year holds outstanding promise for this industry.

Thomas LePorte

* The attendance by executives, engineers, superintendents or other employes of oil companies at these conferences does not constitute an endorsement of the REFINER over any other publication. The fact that men of outstanding ability are allowed to attend these planning conferences shows the interest which companies have in sound editorial content for the benefit of the industry.

## Index


| | | | |
|---|---|---|---|
| What's Ahead for Petrochemicals in '57 | 132 | Oxidation of LPG? | 172 |
| Look at Synthetic Rubber Raw Materials | 138 | Check List for Superfractionator Design | 179 |
| Here's the Outlook for Syndets | 139 | Newest Olefin Polymer—Polybutene | 185 |
| These Petrochemicals Use Ammonia | 145 | Don't Forget Markets in Plant Design | 187 |
| Look Carefully at Acrolein | 151 | Which Polybutene Process | 191 |
| Butadiene, Material of the Future | 157 | Here Are Complete Oxo Reaction Data | 197 |
| Look Again at Synthetic Rubber Industry | 164 | New Separation Tool—Low Temperature | 201 |
| More Ammonia With Least Investment | 169 | | |

# What's Ahead for Petrochemicals

**A quick look at the past and careful study of the present indicates moderate growth and capacity utilization in 1957. An average growth rate of 10 percent for all petrochemicals seems evident.**

**Raphael Katzen**
Cincinnati, Ohio

THE PETROCHEMICAL industry has already entered the period of stabilization and moderate growth previously predicted. There have been practically no shortages encountered during the past year but predictions through 1957 indicate a few tight spots developing.

The most disappointing picture has developed in the field of ammonia and its derivatives, because of the reduced rate of growth of the farm market for fertilizers. With improvements in the farm situation already showing in the last few months of 1956, we can anticipate a gradual recovery of the previous rate of expansion of fertilizer application. Although it may take two or three years for this growth to absorb the expanded ammonia and urea production facilities, plans can now be laid for additional production requirements from 1960 on.

Despite the numerous predictions of rapidly developing novel sources of hydrocarbon intermediates, ethylene still retains its predominant position as a petrochemical raw material. Announced new facilities and expansion of existing facilities will just barely keep ahead of production requirements, and it is anticipated that additional capacity will be required after 1957 to keep up with the steady rate of growth which has been noted.[1] In this respect, the trend toward pipeline distribution of ethylene from large production sources to smaller users may be expected to continue.

A strongly competitive situation may be expected in the field of aromatics production.[2] Although petrochemical production of aromatics has increased rapidly within the last few years, and a further increase is expected during the next two or three years, production from other sources, particularly coke-oven by-product streams, may be expected to increase as the steel industry expands its total production facilities. Quality problems encountered by the steel companies and other by-product aromatics producers, are expected to be overcome within the next two or three years by installation of treatment and refining facilities. Although the market for these aromatics will continue to expand, it is doubtful whether petrochemicals will account for any greater percentage of these products than has been noted to date.

Hydrocarbon polymers will continue to show a major rate of growth. Large polyethylene facilities in low, medium, and high-pressure ranges are being installed, in addition to those in operation, and for the next few years these installations should stay comfortly ahead of market requirements. The technology in this field is changing so fast, however, that it is difficult to predict which area may be subject to greatest expansion.[3]

Synthetic rubber facilities are under expansion now and will be well ahead of immediate requirements in 1957. With technological improvements, however, and the expanding automotive and industrial uses of rubbers having special properties, further expansion can be anticipated in the synthetic rubber field.

The aliphatic chemicals, which were the forerunners of the petrochemical industry, took a back seat for a while as the newer and more glamorous petrochemical products, such as ammonia, synthetic rubber, polyethylene, etc., took the forefront. As the new products have now gone through major expansions, it is found that production of many of the aliphatic chemicals has expanded to levels which push close to the limits of production facilities. Typical of this situation is synthetic ethyl alcohol, which has gradually taken over the market from the natural fermentation product. During the past year, major increases in prices for alcohol have been posted, indicating that the competitive situation is now stabilized, and the synthetic petrochemical product now sets the market pace. With steadily increasing requirements for this basic chemical intermediate and solvent, it is expected that new petrochemical production facilities will be required in 1958 to 1959, or prices will have to increase further to permit the sale of appreciable amounts of the fermentation product. Although ethanol is one of the outstanding cases in this category, the same requirements for additional facilities after 1957 may be antici-

### Watch these petrochemicals in '57

| Pace Setters | Steady Growth |
|---|---|
| Propylene | Ethylene |
| Acetylene | Xylenes |
| Benzene | Phenol |
| Toluene | Ammonia |
| Polyethylene | Methanol |
| Synthetic Rubbers | Iso-propanol |
| Formaldehyde | Butanol |
| Acrylonitrile | Ethylene Oxide |
| Vinyl Chloride | Glycerol |
| Vinyl Acetate | Ethyl Chloride |
| | Urea |

# During 1957

pated for acetaldehyde, butanols, acrylonitriles, acetic anhydride, carbon tetrachloride, vinyl chloride, and other chlorinated hydrocarbons.

In planning for future expansion, the petrochemical producer is well advised to look beyond the glamour of the most popular new products to the large-volume basic synthetic chemicals which are the raw materials for resins, plastics, synthetic fibers, plasticizers, synthetic lubricants, detergents, etc. These basic materials, although already large in production volume, require substantial expansion to keep pace with the over-all growth of market requirements in the chemical and petroleum industries. In practically all cases, processes are well established, specifications are standardized, and production costs are well known. Investments, although showing only moderate rates of return, can be made on a sound basis for the long run.

Petrochemical production for 1955 increased over 1954 at a greater rate than optimistic forecasts predicted. The inventory recession of 1954 depleted stocks to a major extent, and this depletion was made up for in 1955. At the same time, the healthy growth of the chemical and petroleum industries resulted in requirements for additional petrochemicals, so that the combined new requirements and inventory makeup resulted in new record levels of petrochemicals production.

A total synthetic organic chemical production of 74,949 million pounds was achieved, a major advance of almost 22 percent over 1954 production.[4] Basic hydrocarbon intermediates used in petrochemicals production increased by almost exactly the same percentage. Although this growth factor is a very healthy one, the fact that total production of synthetic organic chemicals and hydrocarbon intermediates advanced at the same rate, indicates that other sources than petrochemical grew at the same rate. This means that coal, coke, and other sources of organic chemicals are competing actively with petrochemical sources for the growing markets.

The general advance in petrochemicals production is reflected in practically all categories. In only one instance does the data show a marked decrease, and this may be due to the problem of classification of information. This is in respect to production of "butylenes and mixtures." Slight decreases were also indicated in xylene, isopropanol and ethyl chloride production.

**Prices More Stable**—A general trend toward market stabilization was notable during 1955. Despite decreases in many prices during the early part of the year, resulting from the inventory accumulation of 1954, the subsequent increases in demand to replenish inventories and to take care of increased requirements resulted in generally increasing prices during the latter part of the year.

Price data for the third quarter of 1956, when compared with the same period of 1955 shows the same marked stabilization (Table 1). The largest group of major petrochemicals listed is essentially unchanged in price. Increases are notable in many oxygenated organic chemicals, particularly ethanol. Isopropanol prices reflect the major increase in ethanol prices. This increase is due to the fact that synthetic ethanol has taken over market control from fermentation ethanol, and prices are now being established which have some relation to true production and distribution costs.

Price decreases are noted for only three major petrochemicals. The acetaldehyde decrease of ½ cent per pound is difficult to understand, as the prices of related products made from acetaldehyde have shown increases or are stable. The appreciable decrease in ammonia price reflects the large additional capacity which came on-stream during late 1955 and 1956, paralleled by a decrease in fertilizer ammonia consumption resulting from the farm recession. The lower level of ammonia price of $75 per ton will probably hold for some time in the future, as additional ammonia capacity is still to come on-stream in 1957. Reduction in styrene price probably results from the large increase in production of polyethylene during 1955 and 1956, resulting in more competition in the plastic film and container market.

An interesting feature of the price trends is the fact that this year two prices are quoted for toluene and xylene; 34 cents per gallon for the synthetic petrochemical products, and 32 cents per gallon for the natural coke by-products. The lower price for the natural product results from lower quality. Since the new petrochemical products have established higher quality levels, the natural toluene and xylene producers are looking at the problem of upgrading. Announcements during 1956 by the United States Steel Company and Jones and Laughlin[5] indicate that steel companies producing these cyclic hydrocarbons as coke-oven by-products are adopting petrochemical process techniques to upgrade their inferior products to a point where they can compete with the synthetic output.

**Petrochemical Production Data and Estimates**—The recently issued report of the U. S. Tariff Commis-

**TABLE 1—These price patterns show the ups and downs of some major petrochemicals**
(Cents Per Pound, Except Where Noted)

| | 3rd Quarter, 1955 | 3rd Quarter, 1956 |
|---|---|---|
| **STABLE** | | |
| Acetic Anhydride | 14 | 14 |
| Benzene (per gallon) | 36 | 36 |
| Butadiene | 15 | 15 |
| Ethylene Oxide | 15½ | 15½ |
| Ethylene Glycol | 13½ | 13½ |
| Methanol (per gallon) | 30 | 30 |
| Toluene (per gallon) | 34 | 34 |
| Vinyl Acetate | 16½ | 16½ |
| Vinyl Chloride | 10½ | 10½ |
| Xylene (per gallon) | 34 | 34 |
| **INCREASES** | | |
| Acetic Acid | 9 | 10 |
| Acetone | 7 | 8 |
| Acrylonitrile | 27 | 28 |
| Butanol (sec.) | 11 | 11½ |
| Carbon Tetrachloride | 9 | 10 |
| Ethanol (per gallon) | 40 | 47 |
| Iso-propanol (per gallon) | 39 | 44 |
| Phenol | 17 | 18 |
| **DECREASES** | | |
| Acetaldehyde | 10 | 9½ |
| Ammonia | 4¼ | 3¾ |
| Styrene | 18 | 16 |

sion on Synthetic Organic Chemical Production for 1955 yields data, which along with other published material, aids in making reasonable estimates of further production increases during 1956 and 1957. The production year 1956 is now drawing to a close, and general information is available on the growth of markets and production during this period, which makes possible a reasonable prediction of the amounts of petrochemicals produced during the current year.

As before, the petrochemical items reported in many cases are available from non-petrochemical sources as well. Total production is shown in Table 2, as well as estimates of the proportion of production which is obtained from petrochemical sources, i.e., having petroleum hydrocarbons or natural gas as a base. Where these percentages of petrochemical production are determined from actual data indicating sources, the reference is given. All other percentage figures are estimates of proportions. Some cases are extremely difficult to define; for instance, in the case of phenol, the major part of the total production is synthetic (more than 90 percent, but since this synthesis is based on benzene, which may be obtained from either natural or synthetic petrochemical sources, it cannot be stated with any precision just how much phenol is truly petrochemical in origin.

## HYDROCARBON INTERMEDIATES

**Ethylene**—Despite continued predictions that other raw materials will take over, ethylene remains as the predominant hydrocarbon intermediate for petrochemical production. The 1955 production shows an increase of 30 percent over 1954, a jump which is far greater than was anticipated by any estimates. It is anticipated that continued requirements in 1956 will take production up to a level of 3.2 billion pounds which is just about the limit of existing ethylene producing facilities.

Announcements during the current year of ethylene facilities expansions have been numerous, and of particular interest are the plans of Esso Standard Oil for pipe line ethylene installations both at Baton Rouge and Bayway, which will permit operation of new petrochemical facilities using purchased ethylene. 1957 should see com-

**TABLE 2—Major petrochemical production versus capacity for 1957 compared to total production for 1954 and 1955**
(Millions of Pounds)

| | PRODUCTION | | | | CURRENT ESTIMATES | | |
|---|---|---|---|---|---|---|---|
| | 1954 | | 1955 | | 1956 | 1957 | 1957 |
| | Total Amount | * Percent | Total Amount | * Percent | Production | Production | Capacity |
| **HYDROCARBON INTERMEDIATES** | | | | | | | |
| Aliphatic | | | | | | | |
| Ethylene | 2345 | 99+ | 3048[4] | 99+ | 3200 | 3400 | 3600 |
| Propylene and Mixtures | 1204 | 100 | 1331[4] | 100 | 1500 | 1700 | 1800 |
| Butylenes and Mixtures | 2066 | .... | 1960[4] | 100 | 2100 | 2200 | 2600 |
| Butadiene | 809 | .... | 1411[4] | 100 | 1750 | 1900 | 2000 |
| Acetylene | 424 | .... | 500 | 30 | 650 | 800 | 1000 |
| Aromatic | | | | | | | |
| Benzene | 1880 | 36 | 2250[4] | 32[4] | 2600 | 2900 | 3400 |
| Toluenes | 1160 | 78 | 1340[4] | 77[4] | 1600 | 1800 | 2300 |
| Xylenes | 800 | 90 | 778[4] | 89[4] | 900 | 1000 | 1400 |
| Styrene | 703 | 50 | 1014[4] | 50 | 1100 | 1200 | 1200 |
| **HYDROCARBON POLYMERS** | | | | | | | |
| Polyethylene | 210 | 100 | 402[4] | 100 | 480 | 580 | 700 |
| Synthetic Rubber | 1435 | .... | 1766[4] | 75 | 2000 | 2400 | 3100 |
| **PHENOL** | 418 | 50 | 517[4] | 50 | 570 | 630 | 650 |
| **AMMONIA** | 5440 | 85 | 5600 | 90 | 6000 | 6600 | 9000 |
| **ALIPHATIC CHEMICALS** | | | | | | | |
| Formaldehyde (100%) | 380 | .... | 466[4] | .... | 500 | 600 | 900 |
| Acetaldehyde | 700 | .... | 850 | .... | 900 | 950 | 1000 |
| Methanol | 1132 | 80 | 1359[4] | 85[4] | 1500 | 1700 | 1900 |
| Ethanol | 1430 | 80 | 1470[4] [12] | 83 | 1670 | 1800 | 3200 |
| Iso-propanol | 859 | 100 | 855[4] | 100 | 950 | 1050 | 1200 |
| Butanols | 408 | 52 | 475[4] | 53 | 500 | 550 | 550 |
| Ethylene Oxide | 580 | .... | 794[4] | 90 | 880 | 970 | 1100 |
| Ethylene Glycol | 638 | .... | 888[4] | 80 | 900 | 950 | 1100 |
| Glycerol | .... | .... | 220 | 40 | 250 | 275 | 325 |
| Acrylonitrile | 63 | 100 | 118[4] | 100 | 150 | 200 | 250 |
| Acetic Acid | 461 | 96 | 547[4] | 96[4] | 600 | 650 | 780 |
| Acetic Anhydride | 691 | .... | 842[4] | 96 | 900 | 950 | 1000 |
| Acetone | 478 | 84 | 539[4] | 95 | 600 | 650 | 750 |
| Carbon Tetrachloride | 235 | .... | 287[4] | .... | 300 | 325 | 330 |
| Ethyl Chloride | 547 | .... | 542[4] | .... | 630 | 700 | .... |
| Ethylene Dichloride | 452 | .... | 510[4] | .... | 550 | 600 | .... |
| Trichloroethylene | 297 | .... | 316[4] | .... | 350 | 380 | .... |
| Perchloroethylene | 158 | .... | 178[4] | .... | 200 | 225 | .... |
| Vinyl Chloride | 393 | 80 | 529[4] | .... | 625 | 750 | 750 |
| Vinyl Acetate | 106 | 80 | 134[4] | .... | 170 | 200 | .... |
| Urea | .... | .... | 350[4] | 70 | 400 | 450 | 600 |

*Percent Petrochemical Production.

pletion of construction of these facilities as well as the expanded capacity of others. Even so, 1957 production of an estimated 3400 pounds will closely approach the capacity of expanded ethylene facilities.

**Propylene**—A moderate increase of 10 percent in propylene production yielded 1955 output of 1331 million pounds. A slightly greater rate of growth is estimated for 1956 and 1957 to an estimated 1500 and 1700 million pounds per year respectively, will push closer to the estimated capacity of 1800 million pounds per year.

**Butylenes**—It is most surprising that butylene production is one of the very few areas showing a decrease for 1955 against 1954. The 1955 output of 1960 million pounds per year is about 5 percent less than the 1954 output. It is expected that increased requirements during 1956 will result in the recovery of this market to a level of 2100 million pounds per year, and a moderate 5 percent increase for 1957 should result in an output of 2200 million pounds per year. This will still leave appreciable reserve capacity estimated at a total of 2600 million pounds per year.

**Butadiene**—With operation during 1955 of synthetic rubber plants under private ownership, production requirements jumped so rapidly that butadiene requirements for this industry (as well as other requirements), resulted in an outstanding jump of 75 percent in production to a level of 1411 million pounds. With continued growth of synthetic rubber output it is estimated that butadiene needs will increase further to 1750 million pounds in 1956 and 1900 million pounds in 1957.[6]

Although existing facilities have been pushed as far as possible, and new facilities are under construction, consumption requirements continually run close to the available capacity, and the production potential of 2000 million pounds per year estimated for 1957 will not yield very much margin over requirements.

**Acetylene**—Acetylene has overcome to some extent the initial operating pains of the first petrochemical installations. Because of the nature of acetylene production, which is available from calcium carbide (coke) sources both in large and small installations, and the few large petrochemical operations of Carbide, Monsanto and American Cyanamid, it is difficult to get a true picture of production output. An estimate of the output of major production facilities utilizing both calcium carbide and natural gas for 1955 is 500 million pounds. This is an appreciable increase over 1954, and it is anticipated that an even greater increase up to 650 million pounds will be observed for 1956, going to 800 million pounds for 1957. Expansion of both carbide and petrochemical facilities should yield a production capacity in 1957 of 1000 million pounds per year. Recent announcements of proposed petrochemical installations for acetylene by Rohm and Haas, and Diamond, indicate that new process problems have been overcome to a major extent.

**Benzene**—Benzene production, which rose 20 percent in 1955 to a total production of 2250 million pounds per year, should show an increased output estimated at 2600 million pounds in 1956 and 2900 million pounds in 1957. Capacity from petrochemical sources and coke oven by-product should increase to 3400 million pounds per year in 1957, leaving a substantial margin over requirements.

**Toluene**—Toluene production also increased almost 20 percent in 1955 for an output of 1340 million pounds. Another major increase of about 20 percent is expected for 1956 to 1600 million pounds and a somewhat lesser increase to 1800 million pounds is predicted for 1957. Here again, available supplies from both coke and petrochemical sources are expected to be well over requirements of 1957 production estimated at 2300 million pounds.

**Xylenes**—A production decrease occurred in 1955 for this product, with output of 778 million pounds as compared to 800 million pounds in 1954. Increased market requirements for 1956, however, are expected to jump production to 900 million pounds with a further increase in 1957 estimated at 1000 million pounds. Here again production facilities of 1400 million pounds per year should be ample to take care of these requirements.

**Styrene**—Tying in with the synthetic rubber boom, styrene production increased 35 percent in 1955 over 1954, showing an output of 1014 million pounds. A somewhat more moderate rate of growth is anticipated for 1956 and 1957 with estimated outputs of 1100 and 1200 million pounds per year respectively. There has been some increase in production facilities, but the 1957 estimated capacity of 1200 million pounds per year will be stretched to the limit to meet production requirements.

### HYDROCARBON POLYMERS

**Polyethylene**—The long anticipated growth of polyethylene took the major spurt which was expected in 1955. An increase of more than 90 percent over 1954 output resulted in a total production of 402 million pounds. A somewhat lower rate of growth is predicted for 1956 and 1957, with production reaching 480 and 580 million pounds per year respectively. Considering announcements of major facilities now under construction for low pressure polyethylene, 1957 capacity should reach a total of 700 million pounds, a fair margin over production requirements.

**Synthetic Rubber**—Production of all synthetic rubbers made from purely hydrocarbon raw materials increased 23 percent over 1954. The output of 1766 million pounds does not include such specialized types as the vinyl chloride polymers. An appreciable additional increase in output is estimated for 1956 with a total of 2000 million pounds, and a very major jump is expected in 1957 to 2400 million pounds, to supply the growing demand for replacement and new tires, as well as other rubber uses. Major installations for additional synthetic rubber plant facilities announced in 1955 and 1956 should yield a total capacity by the end of 1957 of 3100 million pounds per year, an appreciable margin over the immediate production requirements.

### PHENOL

The production of phenol increased more than 20 percent to 517 million pounds in 1955. With additional high quality production available from new petrochemical facilities, 1956 output of 570 million pounds, and further growth to 630 million pounds in 1957, is predicted. The estimated production facilities for 650 million pounds in 1957 will leave no appreciable margin over production requirements. Here again expansion of steel mill opera-

tions resulting in more coke by-product production will yield greater competition with petrochemical sources.

### AMMONIA

Although the long predicted glut of ammonia production capacity is now at hand, the picture is made even blacker by the slow-down in the rate of growth of ammonia consumption. The burgeoning ammonia fertilizer market was restricted considerably by farm recession in 1955 and early 1956. The 1955 output of 5600 million pounds of ammonia was only 3 percent over 1954 production. Although 1956 production should increase at a slightly better rate to 6000 million pounds and 1957 production is estimated to increase 10 percent to 6600 million pounds, the existing and new facilities, essentially all petrochemical, will yield a large capacity of 9000 million pounds per year. It has been noted recently that many announced facilities for additional ammonia production are finding it difficult to obtain financing. Geographical shipping requirements, however, might permit a few new producers to operate economically. In general, the ammonia surplus problem will not be solved until major new markets are developed. Major activity is now noted in experimentation on aerial fertilization of forests and pastures, which may yield an economic outlet for some of the surplus.

### ALIPHATIC CHEMICALS

**Formaldehyde**—After suffering a major setback in 1954, formaldehyde production rose 23 percent in 1955 to a total output of 466 million pounds. This should increase to 500 million pounds in 1956 and then take another jump to 600 million pounds in 1957. Although installed capacity has continued to exceed production by a considerable amount, new installations have been announced which should yield a total production capacity of 900 million pounds in 1957. With increased demand, particularly for plastics requirements all over the country, new installations are required so that formaldehyde will be available close to the consumption points.[7]

**Acetaldehyde**—Reliable production data on this product is not available because the major part is consumed directly by the manufacturing companies, in production of derivatives and end products. It is estimated that 1955 production increased appreciably to about 850 million pounds per year, and 1956 production should be 950 million pounds per year. A further increase at a steady rate should be noted in 1957, to a level of 950 million pounds per year. This will approach production facilities of 1000 million pounds per year at the end of 1957.

**Methanol**—Here too, a substantial increase in production for 1955 has been reported. The figure is 1359 million pounds. Another increase is estimated for 1956 to 1500 million pounds, and 1957 should show a total production of 1700 million pounds. Expansion of existing synthetic methanol facilities and completion of new facilities, such as those of Commercial Solvents and Hercules Powder, should yield ample methanol production capacity for 1957 estimated at 1900 million pounds. With increased demand, particularly for production of formaldehyde for plastics purposes, it is anticipated that the margin over production will not exist for any length of time.

**Ethanol**—Although the production increase for 1955 over 1954 was very moderate, indicated as a total of 1480 million pounds, from both synthetic and fermentation sources, a much more substantial increase is estimated for 1956 to a total of 1670 million pounds. 1957 production should increase again to 1800 million pounds. Although the total production facilities reported are 3200 million pounds, the major part of the excess capacity is in fermentation alcohol plants which cannot compete economically today with synthetic, because of the high price of molasses. Synthetic alcohol plant capacities are being pushed to the limit and no additional facilities are under construction or have been announced for 1957. It is indicated that increased market demands will require either more synthetic capacity or a further increase in price to permit production of additional fermentation alcohol.

**Isopropanol**—Production of isopropanol decreased slightly in 1955 to 855 million pounds. A substantial increase is estimated for 1956 to 950 million pounds and a further increase to 1050 million pounds is estimated for 1957. Production facilities in operation by the end of 1957 should total 1200 million pounds, leaving a substantial margin of reserve capacity.

**Butanols**—An appreciable increase in butanol production is reported for 1955, amounting to 475 million pounds. A moderate additional increase is estimated for 1956 to a total of 500 million pounds, and about a 10 percent increase in 1957 is estimated for an output of 550 million pounds. This output will just about match the production facilities available at the end of 1957. It is indicated that additional synthetic butanol capacity will be required.

**Ethylene Oxide**—A 40 percent increase in ethylene oxide production in 1955 over 1954 exceeded practically all estimates. The total output of 794 million pounds should increase again in 1956 to 880 million pounds and in 1957 to 970 million pounds. These rapid increases are attributable to the rising consumption of ethylene oxide in detergents, resins, plastics, and synthetic fibers. Announced increases in ethylene oxide facilities by Carbide, Dow and Wyandotte should be completed in 1957, yielding a total production capacity of 100 million pounds.[8]

**Ethylene Glycol**—Paralleling ethylene oxide production as usual, ethylene glycol showed the same percentage increase for production in 1955. This amounted to 888 million pounds. A substantially smaller increase is estimated for 1956 to 900 million pounds and for 1957 to 950 million pounds. Here again, ethylene glycol facilities are being expanded along with ethylene oxide installations and the total glycol capacity by the end of 1957 is estimated at 1100 million pounds.

**Glycerol**—This product is added to this survey for the first time, as synthetic capacity approaches the 100 million pound per year level.[9] Total production reported in 1955 of 220 million pounds is estimated as being approximately 40 percent from petrochemical facilities of Dow and Shell. With natural glycerol production from soap manufacturers decreasing steadily as synthetic detergents take over a larger portion of the detergent market, synthetic glycerol capacity and production are expected to increase as indicated by announcements of both Shell and Dow concerning expansion of their facilities. 1956 production of all types of glycerol is estimated at 250 million pounds, and should increase to 275 million pounds in 1957. At that time expanded synthetic petro-

chemical installations should result in an increase of total production facilities to 325 million pounds.

**Acrylonitrile**—With growth in markets for acrylonitrile synthetic fiber end products, acrylonitrile production took a major jump of 74 percent in 1955 to a production level of 118 million pounds. This is expected to increase further to 150 million pounds in 1956 and 200 million pounds in 1957. American Cyanamid has already announced an increase in production facilities at New Orleans, and this, together with other smaller installations, should yield a total production capacity in 1957 of 250 million pounds.[10]

**Acetic Acid**—Acetic Acid output increased almost 20 percent in 1955 to a total of 547 million pounds. This should increase to 600 million pounds in 1956 and 650 million pounds in 1957. Estimated production facilities of 780 million pounds in 1957 are more than ample for these requirements.

**Acetic Anhydride**—Also showing an increase of a little more than 20 percent, acetic anhydride output is reported at 842 million pounds for 1955. This should increase to 900 million pounds in 1956 and 950 million pounds in 1957. This last figure will approach production facility capacity of 1000 million pounds closely, and additional capacity may be required in the near future.

**Acetone**—Acetone production increased to 539 million pounds in 1955, and should reach 600 million pounds in 1956 and 650 million pounds in 1957. A substantial increase in synthetic acetone facilities, particularly in the co-product of synthetic phenol manufacture, should result in an increase in acetone capacity to an estimate of 750 million pounds per year by the end of 1957. This is ample for the requirements at that time.

**Carbon Tetrachloride**—An increase to 287 million pounds in 1955 should be followed by further increases to 300 million pounds in 1956 and 325 million pounds in 1957. The estimated capacity of 330 million pounds will leave no margin for 1957 production, and additional facilities will be required within the next two or three years.

**Ethyl Chloride**—Ethyl Chloride production decreased slightly in 1955 to 542 million pounds. This decrease should be more than made up by the estimated 1956 production of 630 million pounds, and a further increase is estimated to 700 million pounds in 1957.

**Ethylene Dichloride**—The production of this chlorinated hydrocarbon increased to 510 million pounds in 1955 and is estimated to show further increases in 1956 and 1957 to 550 and 600 million pounds respectively. With no additional production available as a by-product of ethylene oxide production by the chlor-hydrin process, other synthesis facilities may be required in the near future.

**Trichloroethylene**—This product showed a substantial increase to 316 million pounds in 1955 and should increase further in 1956 to 350 million pounds. 1957 production is estimated to increase to 380 million pounds.

**Perchloroethylene**—An output of 178 million pounds in 1955 is more than a 10 percent increase over 1954 production. This rate of increase is expected to hold for 1956 and 1957.

**Vinyl Chloride**—This is one of the major gorwth chemicals, showing a 35 percent increase in 1955 to a total of 529 million pounds. Increased plastic and synthetic fiber requirements have accounted for this major increase, and a substantial rate of growth of about 20 percent per year is anticipated for 1956 and 1957, for totals of 625 and 750 million pounds respectively. The 1957 production will be pushing estimated capacity of 750 million pounds, so that additional manufacturing facility requirements are indicated.

**Vinyl Acetate**—Production of vinyl acetate increased about 30 percent in 1955 to 134 million pounds. A substantial increase to 170 million pounds is estimated for 1956 and a further increase to 200 million pounds is estimated for 1957 because of growing plastic requirements.

**Urea**—Urea is being reported in this summary for the first time, as petrochemical production exceeds the 100 million pound per year mark. The Tariff Commission report shows urea only in fertilizer products. Separate figures are given for urea resins, which may be factored to yield an estimate of urea content. The production figure of 350 million pounds reported for 1955 is the sum of fertilizer and resin data. It is estimated that 70 percent of this is of petrochemical origin. A further increase to 400 million pounds is estimated for 1956 and to 450 million pounds for 1957. This rate of growth is slower than previously anticipated, mainly because of the slowdown in growth of farm purchases of fertilizer materials. 1957 capacity of an estimated 600 million pounds is substantially more than estimated requirements for that year, but further fertilizer requirements developing in the next two or three years should take care of this capacity.

### Meet the Author

DR. RAPHAEL KATZEN graduated from Polytechnic Institute of Brooklyn in 1936 with a B.S degree in chemical engineering, then received his M.S. degree in 1938 and his Ph.D. degree in 1942, both in chemical engineering from the same school. He gained a great deal of technical experience by working for Cellutate Inc., Northwood Chemical Company, Diamond Alkali, Inc., and Vulcan-Cincinnati, Inc. Early this year, Dr. Katzen organized Raphael Katzen Associates International, Inc., which consists of a group of consulting engineers and scientists engaging in consulting activities in petrochemicals and organic chemicals from Canada to Latin America. Presently he is president of this firm which is located in Cincinnati, Ohio.

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## '56 Petrochemicals

# Look at Synthetic Rubber Raw Materials

**Here is a capsule of the entire monomer and polymer supply situation.**

**John T. Cox, Jr., and W. Whitney Weinrich**
Washington, D. C.

THE MOTTO of the synthetic rubber industry for 1956 was "expansion." In every facet of this newest industrial giant, one saw construction, new products and new plans. Technical progress was at a rate that foretells America's almost complete independence of offshore ELASTOMERs.

This brief summary will give a synopsis of the monomer and polymer situation as they currently exist.

## MONOMERS

**Butadiene**—This is the principal monomer of the synthetic rubber industry. Although produced from refinery by-products the present expansion picture is centered around dehydrogenation of n-butane.

Butane at 5.5 cents per gallon gives a two-cent per pound feed cost advantage over normal butylenes at 17.5 cents per gallon. This ratio should be maintained for some time in spite of a very firm butane market.

1959 butadiene requirements are expected to be 1,050,000 short tons. By 1957, production will be near 718,000 short tons with an additional 143,000 short tons coming on stream. In 1958 there should be 860,000 short tons of capacity leaving 190,000 tons of additional production to be built for the 1959 expected demand. This pre-supposes that no other large scale use of butadiene will develop. Rumors and proposals are rampant but no facts are known.

**Styrene**—The other monomer of synthetic rubber continues to mount in volume. Expansion plans in this field have been severely curtailed. The only plant proceeding now is Cosden Refining at Big Spring, Texas.

Benzene so necessary for styrene production is in uneasy balance. The oil industry must double its present capacity of 140 million gallons in the next 5 to 8 years, or styrene manufacturers will import 50 to 55 million gallons to make up the difference. Ethylene, the other ingredient, is in good supply.

Monomers used in the specialty rubbers have expanded this year. Acrylonitrile facilities have kept pace with requirements and neoprene facilities are expanding.

**TABLE 1**
**Expansion Pattern for the Various Elastomers**

| COMPANY | Capacity 1955 | Capacity 1957 |
|---|---|---|
| **GR-S** | | |
| Firestone | 130,000 | 230,000 |
| Goodrich-Gulf Chemicals | 212,000 | 220,000 |
| Goodyear Tire and Rubber Co. | 115,200 | 192,000 |
| Texas-U.S. Chemical | 88,000 | 111,600 |
| Shell Chemical | 89,000 | 110,000 |
| Phillips Chemical | 63,000 | 108,000 |
| Copolymer Rubber and Chemical | 49,000 | 69,000 |
| American Synthetic Rubber | 44,000 | 68,500 |
| United Carbon | 44,000 | 44,000 |
| General Tire and Rubber | | 40,000 |
| U.S. Rubber | 22,200 | 30,000 |
| Total | 856,400 | 1,223,100 |
| **NITRILE** | | |
| Various-Total | 50,000 | 66,000 |
| **BUTYL** | | |
| Esso Standard Oil | 47,000 | 47,000 |
| Humble Oil | 43,000 | 44,500 |
| Total | 90,000 | 91,500 |
| **NEOPRENE** | | |
| E.I. DuPont | 100,000 | 125,000 |
| GRAND TOTAL | 1,096,400 | 1,505,600 |

The future of the new "synthetic natural rubber" is hinged on the cost of isoprene. Raw materials for isoprene production are in high demand for aviation fuels. There are many possibilities being investigated as a starting material for isoprene.

## POLYMERS

Emphasis of the keynote "expansion" is shown in Table 1. It is obvious that the oil industry has a big share of this new industry. This is only natural because most of the raw materials are petroleum based, as the interest and participation increases, the consumption of synthetic will further shrink the natural rubber market. The ratio of natural to synthetic is now 40:60 and is predicted to be 25:75 by 1960 with total U. S. consumption nearing 2 million tons.

The most significant polymer development of 1956 was the large semi-plant polymerization of cis-polyisoprene, "natural synthetic" rubber. This indicates our complete independence from natural supplies if need be.

In the field of styrene-butadiene polymers the most talked about development is the new type of polymerization reactors. Reports are of very short-time reactions with high conversion per pass. Also, a new type of extruder-dryer for polymers is undergoing tests to determine its capacity and long run conditions.

Petrochemicals 56

# Here's the Outlook for Syndets

**Petroleum derived detergents are a big business. Current production, latest developments and future trends of these important petrochemicals are discussed.**

**Foster Dee Snell**
Foster D. Snell, Inc.
New York City

WHEN A GROWING industry doing upward of a half billion dollars annually in domestic business has to convert more than half its production from one product to a successful competitive product in the course of ten years, that's news. Such changes have occurred interindustry, as to the change to nylon from silk, or to rayon from cotton.

While the term syndets is for synthetic detergents, usually limited to detergent products, surfactant is a broader term covering all surface-active agents such as emulsifiers and wetting agents. In addition to cleaning, syndets may be employed as emulsifiers and wetting agents. However, a number of products belong in the two latter groups which are unimportant in detergent properties.

Figure 1 shows the changes in poundage in sales of soap and syndets for the first half of the various years.

Syndets have been on sale in the U. S. since 1932. For various reasons, first slow public acceptance and later raw material shortages, reliable figures for syndets are not available prior to 1948 but they are small. Figure 2 shows the change in annual dollar sales of soap and syndets. All of these figures are low as some of the lesser producers' data are not available.

The syndets seldom contain over 40 percent of surfactant and often only 20-25 percent. Therefore, Table 1 shows a comparison of the production of surfactants on a 100 percent-active basis with syndets on an as-sold basis. The builders which make up the balance of many syndets result in better performance than is obtainable with the 100 percent active agent. The figures for surfactants include many not usable in syndets, sulfated oils, for example. The table indicates that roughly less than half of surfactant production goes into commercial syndets.

While the increased sale of syndets has come about substantially by replacement of soap by syndets, the latter find uses where soap could never be used, such as in acid solution, or in solutions of strong electrolytes.

**Meet the Author**

FOSTER DEE SNELL was born in Binghamton, N. Y. He received a B. S. degree from Colgate University in 1919, an A. M. degree from Columbia University in 1922, and a Ph.D. degree from Columbia in 1923. In addition to being president of Foster D. Snell, Inc., Foster D. Snell Research, Inc., and Foster D. Snell Foundation, Inc., he still manages to devote a tremendous amount of his time and effort to other activities. He is a member of numerous honorary clubs and fraternities, and more than a dozen scientific organizations, in many of which he has held or still holds some office. Snell has published over 60 articles, six books, and holds more than 30 patents.

Figures for the first six months of 1956 show that although the decline was only 1.5 percent for soap sales compared with the same period in 1955, syndet sales increased 25 percent in tonnage and 19 percent in dollar volume. The increase is quite largely in the second quarter. This indicates that soap sales are leveling off from their decline while syndet sales continue to climb. The value of the latter for the first six months of this year exceeded $300 million.

Growth of syndets can be explained as due to development of new special purpose products, but more particularly to new applications non-competitive with soap, requiring relatively large volumes of the syndet. In the recent past, 85 percent of syndets went into household detergents, which shows the importance of their relation to soap. Examples of uses which may modify this proportion are inclusion of small amounts in poultry and stock feed, use in soil conditioning, and use in oil-field flooding.

Petroleum-based surfactants are of three general types—anionic, nonionic, and cationic, the first being the type most largely produced. There is no clear line of demarcation, a syndet

**TABLE 1**
**Total Production of Surfactants (thousands of pounds)—100 Percent Active Basis, and Syndets—As-Sold Basis**

| | Surfactants | Price Per Pound | Syndets |
|---|---|---|---|
| 1948 | 374,715 | 0.32 | 401,863 |
| 1949 | 428,460 | 0.25 | 712,456 |
| 1950 | 673,678 | 0.23 | 1,093,188 |
| 1951 | 688,904 | 0.21 | 1,434,000 |
| 1952 | 736,401 | 0.20 | 1,530,000 |
| 1953 | 914,713 | 0.20 | 1,867,000 |
| 1954 | 1,025,836 | 0.26 | 2,063,000 |
| 1955 | ..... | .... | 2,317,000 |

U. S. Tariff Commission — Assoc. of American Soap & Glycerine Producers, Inc.

## Here's the Outlook for Syndets . . .

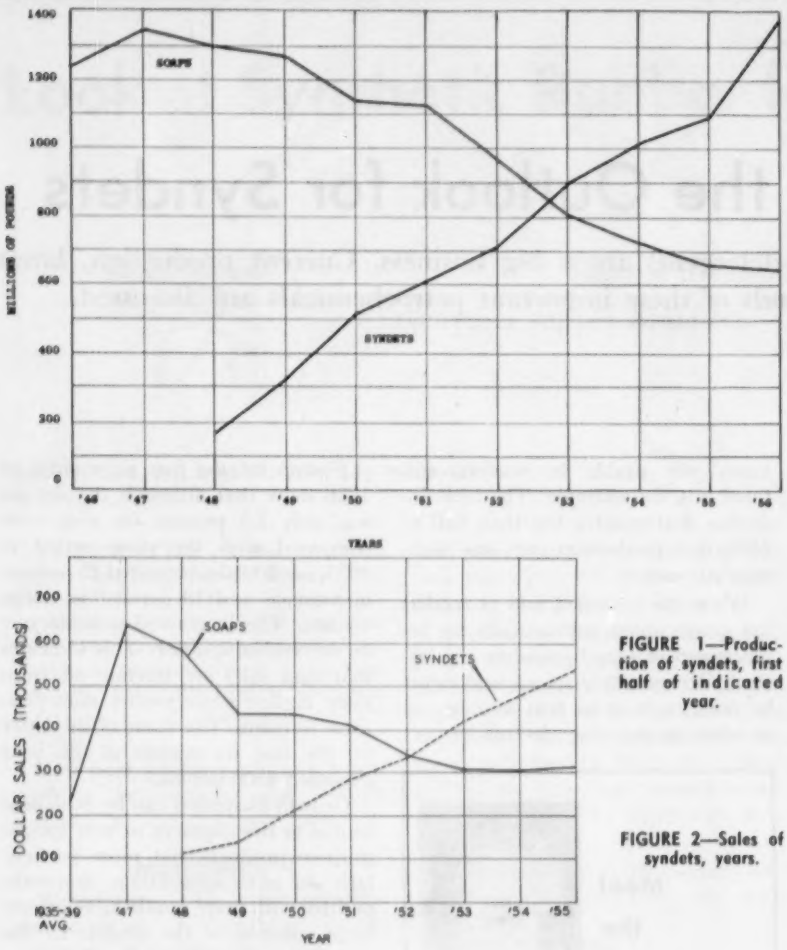



FIGURE 1—Production of syndets, first half of indicated year.




FIGURE 2—Sales of syndets, years.

may be made, for example, by adding ethylene oxide to a long-chain alcohol from petroleum, or one from the fat industry. Representative of the rate of increase of petroleum-based products, Figure 3 shows the figures for dodecylbenzene sulfonate on a 100 percent-active basis. There is a slight trend toward dodecylbenzene sulfonate as commanding a smaller percentage of the total market. Specifically, for 1952 to 1954 this was 51.4 percent, 50.4 percent, and 49.8 percent. Figures for 1955 are not yet available.

**Anionics**—Petroleum-based syndets are estimated to represent 80 percent of the total produced for the household market. The bulk of the commercial products is in the form of the alkylaryl sulfonates, specifically, sodium dodecylbenzene sulfonate. Prior to 1940 the alkylate was made largely from benzene and keryl chloride, the latter being produced by chlorination of low-aromatic kerosene fractions. That process is now obsolete in the U. S. Currently the alkyl group is derived from propylene tetramer and benzene. Thereafter the sulfonate is produced with sulfuric acid or anhydrous sulfur trioxide and neutralized with caustic soda. In discussion of sulfonates and sulfates, the sodium salt is taken for granted.

Propylene tetramer is made by a number of large oil companies for their own use or for sale. Several large oil companies make the alkylate and at least one large chemical company makes its own. A Canadian plant is under construction to make both alkylate and tetramer.

Many of the petroleum companies also sulfonate alkylate and sell the product as a dry product or as a slurry. They also sell to large and small sulfonators. A recent product offered is dodecylbenzene sulfonic acid for blending with builders and neutralizing by the compounder. The trend has been toward a product containing less unsulfonated material and one with a better odor. Some years back alkylate made from toluene was marketed but deliquescence of the sulfonate produced from it caused it to be discontinued.

Continuous sulfonation with either oleum or sulfur trioxide is on the increase. While the established plants will no doubt continue to use the batch method employing oleum, new plants being built—at least the larger ones—are likely to use a continuous process. A plant is under construction in Ontario, Canada, to produce dodecylbenzene sulfonate with sulfur trioxide and thus reduce the present Canadian imports of syndet slurry.

When produced batchwise the sulfonate is diluted with water to separate incompletely into two layers, spent acid and alkylate sulfonic acid. An advantage of continuous sulfonation with sulfur trioxide is a large reduction in excess sulfuric acid and avoidance of the separation by dilution. Further, the neutralization with caustic soda results in a relatively small proportion of sodium sulfate in the final sulfonate. Stabilized liquid anhydrous sulfur trioxide requires extremely careful handling because it solidifies readily on contact with moisture.

In light-duty products suitable for washing woolens and for hand dishwashing, 40-70 percent of sodium sulfate is allowable and is a builder. High sodium sulfate-containing products therefore have had a natural outlet. This type of product has become progressively less important. This high proportion of sodium sulfate is not permissible in heavy-duty products, typically intended for use in the washing machine.

Heavy-duty granular products, or general detergents, usually contain about 20-25 percent of active agent which is most commonly sodium dodecylbenzene sulfonate, with most of the balance consisting of various less expensive but effective builders. For example, as much as 50 percent of sodium tripolyphosphate is present in some heavy-duty products. Reduction in the proportion of active ingredient from that of the light-duty syndets roughly offsets the more expensive types of builders used to give a house-

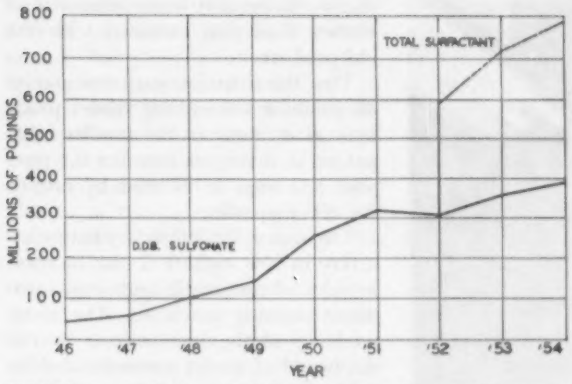



FIGURE 3—Production of dodecylbenzene sulfonate—100 percent active basis.

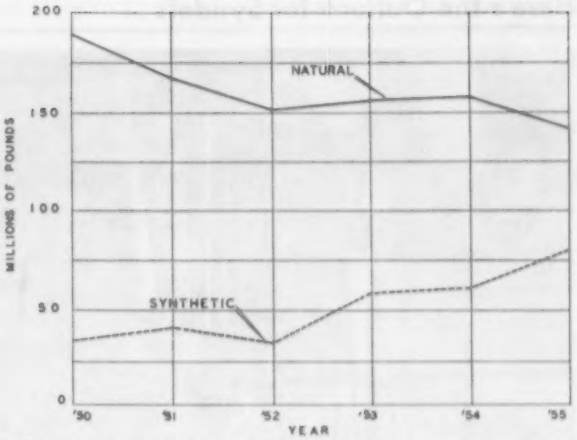



FIGURE 4—Snythetic from petroleum starts to take over the natural glycerine market.

hold product competitive in price with the standard granular soap products built with alkaline salts. This, as well as the good performance of syndets in hard water and their easy rinsability, accounts for the changes in the relative soap-syndet picture. Other additives to syndets not discussed here in detail include sodium carboxymethyl cellulose to reduce graying of fabrics by redeposition and improve suspensibility of soil, optical bleaches to improve the apparent whiteness of fabrics, suds builders to improve the volume and stability of foam, sodium silicate as an anti-corrosion agent to reduce attack on metals and in particular on aluminum, and even materials to reduce yellowing of silver.

Research is in the direction of improving the physical properties of dodecylbenzene sulfonate and its built products. For instance, a 1956 patent claims a method for making "pure white" alkylaryl sulfonates by chlorinating the alkyl hydrocarbon, separating pure alkyl monochlorides, and reacting these with an aromatic hydrocarbon such as benzene in the presence of aluminum chloride and aluminum chloride contact oil. Pure mono-alkyl aromatics are separated by distillation, sulfonated, and neutralized. Improved color of a 50 percent dodecylbenzene sulfonate slurry is claimed in another 1956 patent by addition of a highly siliceous sodium silicate in sodium hypochlorite bleach solution. The practice of bleaching alkylaryl sulfonate with sodium hypochlorite has been common. In some cases optical bleaches not substantive on fabrics are added only for the purpose of causing the granular product to look whiter.

Another 1956 patent claims inclusion of 2-6 percent of low molecular weight sulfate esters as additives to reduce the caking tendency of built granular dodecylbenzene sulfonate products. Examples are the sodium salts of methyl, ethyl, or isopropyl sulfate.

**Liquids**—The first liquid syndets were shampoos, high in price and negligible tonnagewise, although they largely replaced soap shampoos. Then petroleum-derived nonionics were offered to the public in concentrated form for general purpose use—liquid because only liquid nonionics were then available. Relatively low sudsing was tolerated and success was fair for a time. But anionic products in fairly concentrated solution entered the field and had better foaming power. These soon contained alkylaryl sulfonates. They were not built. The market for these products was largely limited to the household dishwashing and washbowl laundry. The popularity of liquid syndets for washing dishes is probably due to their immediate solution in water. Liquids for special purposes have also been produced. Some of these have been advertised as "cold-water" cleaners. Another type is a liquid detergent and sanitizer for washing painted woodwork and other hard surfaces.

The most recent development has been liquid built detergents specified for heavy-duty use and, therefore, competitive with the standard granular products. Either potassium salts are used to increase solubility or alcohol to serve as a solvent. Nonionics of the condensed amine type serve both as suds builders and help to solubilize the alkylaryl sulfonate which is the main active agent.

The increase in sale of liquid products has been phenomenal. In 1955 sales of liquid syndets increased 30 percent over those of 1954. During the first half of 1956 sales at 130 million pounds jumped 86 percent above those of the same period in 1955. That, however, is less than 10 percent of the total syndet sales.

But now is the time to take a look at Table 2. The pounds of liquid syndets is seven times that of liquid soaps, with a valuation thirteen times that of the liquid soaps. That does not mean that the syndets were more expensive per pound of solids. Most liquid syndets are over 50 percent solids. No liquid soap is that concentrated and much is sold at 15 percent solids. Similarly syndet shampoos are currently nearly twenty times soap shampoos at approximately the same price per pound.

**TABLE 2**
**Sales—First Half of 1956**

| | Pounds (Thousands) | Dollars (Thousands) |
|---|---|---|
| Solid Soaps | 631,157 | 150,061 |
| Solid Syndets | 1,246,239 | 249,566 |
| Liquid Soaps | 18,544 | 4,043 |
| Liquid Syndets | 130,072 | 53,095 |
| Soap Shampoos | 680 | 627 |
| Syndet Shampoos | 13,192 | 11,871 |

Even the lowly scouring powders come into the picture. They used to contain a small percent of soap, often insufficient to foam in very hard water. Now they contain syndets instead, often scrap from the production in other physical forms.

**Low Sudsers**—Every commercial

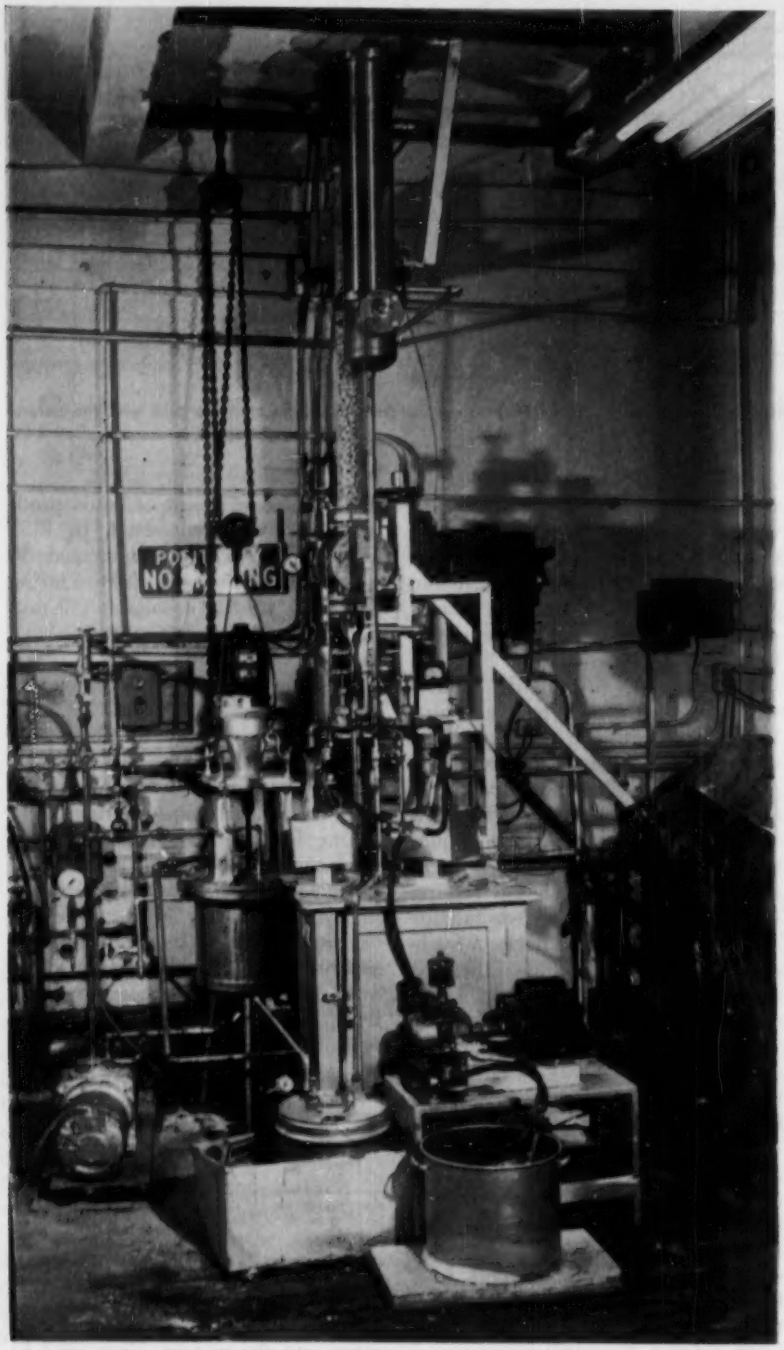


FIGURE 5—Pilot plant for production of nonfatty-acid esters of sucrose, possible competitor of sodium dodecylbenzene sulfonate.

laundry has known for decades that there was such a thing as too much soap as well as too little. The surplus suds interfered with the mechanical detergency resulting from the drop of the fabric in the wheel. When automatic washers came out as miniature horizontal washwheels, the public learned the lesson and figuratively called for low sudsers.

Low sudsers cannot be put in a single class. Some contain alkylaryl sulfonates in relatively low proportion, some are based on nonionics. One popular product was for a long time the addition product of tall oil and ethylene oxide. Currently an improved version of this product is said to give 50 percent better whiteness of clothes than that obtained with the old product.

The three major soap companies all produce low-sudsing syndet products, as do some of the smaller companies. A detergent base for the purpose has been announced by one of the oil companies.

The reason for interest by manufacturers in low sudsers is the increase in sales of automatic and semi-automatic washing machines. The usual tendency of the housewife is to use the brand of syndet recommended by the manufacturers of her machine. The trend by the manufacturers is to recommend low sudsers. In 1952 production of automatic and semi-automatic washers passed that of spin-wringer types. This change continues to accelerate.

**Competition**—The major competitors of petroleum-based anionic detergents in the past have been the sulfated fatty alcohols. The trend is shown in Table 3. For reasons discussed later, this trend may be reversed in the future.

**TABLE 3**
**Production of Anionic Syndets**
**(Thousands of Pounds)**

| YEAR | Cyclic Anionics Mainly Petroleum-Derived | Non-Cyclic Anionics Mainly Not Derived From Petroleum | Percent Mainly Petroleum-Derived |
|---|---|---|---|
| 1947 | 66,229 | 101,859 | 39.5 |
| 1952 | 362,001 | 130,464 | 73.5 |
| 1953 | 417,870 | 134,765 | 75.0 |
| 1954 | 448,136 | 138,655 | 76.5 |

**Nonionics**—Many of the early nonionics were of the condensed amine type such as that resulting from the condensation of fatty acid with excess diethanolamine. Such a product is necessarily fairly expensive since both mono- and diethanolamine are about 25 cents a pound. This type of nonionic is still produced and finds many special uses. Condensed amine nonionics augment and stabilize the foam of dedodecylbenzene sulfonate. Larger quantities of nonionics are made, based on ethylene oxide, which is about 15 cents a pound. Examples are products made by condensing many molecules of ethylene oxide with a fatty alcohol or thio-alcohol, with an alkyl phenol, with a fatty acid, or with tall oil. The latter gives an inexpensive nonionic, but one somewhat low in detergent power by itself. Nonionics are now about 20 percent of the

syndet market.

Because of diminished soap production, inedible tallow is readily available at a stabilized price of 7 cents a pound. From this, relatively low-cost fatty alcohols are made for use in making both nonionics and anionics. When these alcohols are fractionated into a simple chain length, they become expensive. A cheaper $C_{12}$ thioalcohol is made by the reaction of isobutylene and hydrogen sulfide but this is a branched-chain alcohol rather than the straight chain made from fat sources. A mixed straight-chain alcohol derived from animal fats by sodium reduction contains principally cetyl, stearyl, and oleyl alcohols. This sells for 35 cents a pound but, of course, costs much less to the large manufacturer who produces it on a large scale and uses it in his own products.

While the early ethylene oxide addition products were liquid nonionics and as such presented problems arising from their physical form, one class is derived from ethylene oxide and propylene oxide as solid products.

In a 1956 patent, a nonionic is formed by the reaction of an alkylolamine with a fatty acid halide and a cyanate. The resulting compound is stated to increase the detergent effectiveness of built dodecylbenzene sulfonate products on both cotton and wool. In another recent patent a liquid or semi-liquid ethylene oxide condensation product is sorbed by salt builders in such a way as to give a non-sticky granular product. During the mixing of the ingredients, enough water is added to form a hydrate of the salt used as a builder.

In general, nonionics have been more expensive to produce than anionics. A new nonionic however, is made by esterifying tallow or other fat with sucrose. These sugar esters could be low in cost since tallow is about 7 cents a pound and sugar 5-8 cents according to the degree of purity. In the laboratory they have been found comparable to dodecylbenzene sulfonate products as detergents. At present they are in the pilot plant stage.

Nonionic uses include processing synthetic fibers, processing cotton, scouring wool, processing leather, emulsifying insecticidal agents, and emulsifying cosmetic products. They are also used in combinations with anionics and cationics.

While nonionics are considered not to ionize, a study of their behavior shows that at times they behave like a huge cation in balance with a hydroxyl radical. The evidence for this is that they form loose addition compounds with anionics, and with phenols. However, they can be considered as relatively less reactive and more stable than anionics or cationics.

A recent development in use of nonionics is to so alter the surface properties of drilling mud as to permit drilling at bottom-hole temperatures in excess of 400 F. and in one well at a depth of over four and a quarter miles. Thus a product of the petroleum industry is cannibalized—indirectly—to assist the petroleum industry.

**Cationics**—Cationics have a large positively charged group in balance with a halide ion, usually the chloride. Those best known are the quaternary ammonium halides. They have been used mostly for their high germicidal action, for example, in cleaner-sanitizers useful in dairies and food-processing plants. In these they are combined with a small amount of nonionic and alkaline salts to give good wetting, cleaning, and sanitizing action. Their emulsifying power has been found useful in special applications, one example being to emulsify pentachlorophenol in water for use as a herbicide and soil toxicant.

Alkane may be used as the starting material from which an aromatic chloride is formed. In turn, this is reacted with an amine such as triethanolamine to form a quaternary ammonium chloride. The product is relatively expensive as triethanolamine is 22 cents a pound.

Cationics are incompatible with anionics as one precipitates the other much as acid neutralizes an alkali. Because of this, a proposed use given in a British patent is to minimize foaming of sewage effluents caused by the presence of anionic surfactants.

**Foreign Markets**—Inherently the production of alkylate is an operation to be carried out only on a large scale. In contrast to that, sulfonation is an operation readily carried out locally on a modest scale. Therefore, foreign producers have normally imported alkylate for a time to break into the market; later if the country is large enough, local manufacture follows. Foreign countries are following the lead of the United States in syndets to a variable degree. Of course, the per capita consumption of all detergents—soap and syndets—must be considered. For example, it is about 25 pounds per capita in the U. S. and the United Kingdom, but less than 5 pounds per capita in Japan.

The United Kingdom imported modest amounts of alkylate around 1950, mostly from Trinidad but some from the United States. Later local manufacture from keryl chloride was started by one producer. More recently change has been made to more modern processes.

While 1951 showed 15 percent of all detergents in the United Kingdom as syndets, 1954 showed over 25 percent and the ratio is increasing rapidly. Italy and France lag behind that. In all cases European data are less definite than U. S. Israel has reached about 50 percent syndet consumption but is an exception to the usual smaller percentage for the more remote countries. Even Canada has not kept up with the U. S. in syndet consumption.

Alkylate production by major chemical companies such as Montecatini, Kuhlmanns, etc., is under way in Italy, France, Western Germany, and spreading. A major source of delay in marketing of syndets abroad has been the same as in the U. S., the limited availability of molecularly-dehydrated phosphates. This is also in process of correction in many countries, but prices are in general higher than in the U. S., another retarding factor for syndets. The relative hardness or lack of hardness of local water supplies is another significant factor.

So Table 4 shows some interesting world estimates. If the rest of the world considered follows the U. S. trend to the point of even 50 percent of total detergent consumption being syndets, it would result in 2 billion pounds additional syndet production. Probably the strong trend toward a higher standard of living throughout the world, which means among other things more detergents, is important in predicting the future trends. Thus the meaningless average of the 32 nations excluding the U. S. is 8 pounds per capita, pulled down by such countries as India with 372 million population at less than a pound per capita.

But we have recently installed a syndet plant in Ceylon and even had an inquiry for one for Tahiti.

**TABLE 4**
**Some World Estimates on Markets for Soap and Syndets**

| Countries Considered | 33 |
|---|---|
| Total population | 1.08 billions |
| Consumption of soap | 7.9 billion pounds |
| Consumption of syndets | 3.6 billion pounds |
| Total soap and syndets | 11.5 billion pounds |
| Percentage as syndets | 31% |
| Consumption of soap excluding U. S. | 6.2 billion pounds |
| Consumption of syndets excluding U. S. | 1.2 billion pounds |
| Total soap and syndets excluding U. S. | 7.4 billion pounds |
| Percentage as syndets excluding U. S. | 16% |
| Consumption of soap and syndets per capita | 10.6 pounds |
| Consumption of soap and syndets per capita excluding U. S. | 8.0 pounds |

So, in general, the world market can be expected to follow the U. S. in taking up syndets.

**Glycerine**—Every pound of soap yields around eight-hundredths of a pound of glycerine. The price of glycerine affects the price of soap. At a high enough price for glycerine, the soap would become the by-product and could be sold at little more than the cost of packaging and transportation. A pound of syndet rarely is accompanied *per se* by any glycerine production, the exception being limited types of fat-derived products counterbalanced by other syndets such as stearyl monoglyceride which consume glycerine.

When the trend toward syndet production became evident, it favored synthetic glycerine. In 1950 there was 35 million pounds so produced, equivalent to over 15 percent of the national supply. It wasn't enough. The price stayed high in 1951 at over 50 cents per pound for the 95 percent CP grade. The rate of production went up and the price down. Production figures are shown in Figure 4. So in late 1955 the price was 30 cents and production capacity at a rate of 115 million pounds annually. Currently it has dropped to 28 cents and stocks are above normal. A multipurpose plant coming into production in the next year or two can use allyl alcohol and hydrogen peroxide to produce glycerine. Other capacity is in the discussion stage. Meanwhile the Pharmacopoeia prohibition against any residual chlorine in glycerine has been relaxed. The XV Edition permits 10 ppm. of chlorine.

Here petroleum has taken over where the soap industry supply was inadequate, and synthetic glycerine capacity will soon exceed the natural supply of about 140 million pounds annually, a trend which will not be reversed. Consumption may reach 260 million pounds before five years are out, assuming no unexpected developments. In fact, that segment of the industry appears headed for that norm of at least parts of U. S. industry, operation at about 75 percent of installed capacity.

**Benzene**—The demands of the syndet industry for alkylate were one of the causes of rapid expansion in production of petroleum-derived benzene. The latter has set new standards so that coke-oven benzene is now purified to meet standards set by the petroleum-derived product. Prices of upwards of 50 cents per gallon have been reduced to about 35 cents by competition between the two sources.

**Phosphates**—The market for molecularly dehydrated phosphates was originally built by tetrasodium pyrophosphate for addition to heavy-duty soaps. That has in turn taken a rear pew to give way volumewise to sodium tripolyphosphate and closely related types which are the preferred builders for solid syndets. Currently speculation is rife as to the volume of tetrapotassium pyrophosphate that will be required for heavy-duty liquid syndets.

Lack of availability of such builders deferred syndet expansion in the late 1940's. Production caught up with consumption in early 1950 so that completely free competition between soap and syndets existed for several months. Then the race to catch up on phosphate builders was on again with diversion of much elementary phosphorus from this use to that of the military. Currently supply has caught up with demand. An educated guess indicates that over a billion pounds of sodium tripolyphosphate going currently into solid syndets.

**Heavy Chemicals**—In brief, a considerable amount of caustic soda required in soap production is replaced by soda ash in manufacture of polyphosphates. In addition a new factor introduced by syndets is the requirement for sulfuric acid or sulfur trioxide.

**Clouds on the Horizon**—The clouds referred to are for the petroleum industry which today has a volume in the detergent—meaning cleaning product—industry which it has never before enjoyed.

The fixing of the price of tallow by surpluses in the range of $7 \pm 1$ cent per pound poses one threat. Use in cattle feed of the excess over exports serves to arbitrate the price at that level. Reduction to tallow alcohols, either by sodium or hydrogenolysis, followed by sulfation and neutralization, produces a product competitive with that from alkylate when detergency is evaluated. Any change in demand for export tallow might depress the price and affect the competitive situation.

Export markets for alkylate cannot be expected to continue indefinitely. So long as production of syndets abroad is expanding, it produces new markets at roughly the rate that foreign production takes some away. Thus the large European countries now have alkylate producers who will sooner or later compete with the U. S. for export markets.

New products, either on the horizon or not yet even out of the research laboratory, could produce substantial competition. A straight chain from a natural source is always preferable to the branched chains of petroleum products. A partial example from within the petroleum field is the failure of tributylene to compete successfully with tetrapropylene. Various programs under way for the utilization of tallow in syndet synthesis are currently leading to publications and may lead to products.

In short, this story has been of a revolution over a ten-year period. Anyone familiar with the dynamic changes occuring in the chemical field, the progressive increases year by year in research expenditures, and productivity of research could hardly predict that the leading products today would be leaders twenty years hence. Ten years hence maybe!

In concluding, it is striking to recall that many years ago one of the big soap companies spent many millions of dollars in an effort to produce fatty acids from petroleum. They were successful but the soap made from them was unsatisfactory. Yet, at this later date, the soap industry has become a significant customer of the petroleum industry to produce widely sold surfactants derived from petroleum—but not as soap. # #

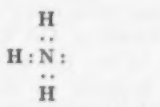
# These Petrochemicals Use Ammonia

**Here are just a few of the many non-fertilizer uses of ammonia. These chemical uses will soon justify the rapid expansion in ammonia production.**

**Lewis F. Hatch**
University of Texas
Austin

AMMONIA IS a many splendored thing. It makes the grass greener and the trees more fruitful. This is impressive to an agchemist.

Ammonia also has three replaceable hydrogen atoms and two extra electrons.



This is impressive to a petrochemist. Many things make the grass green, but only ammonia has three replaceable hydrogen atoms, two extra electrons and costs only two and one-half cents a pound.

The production figures for ammonia are equally wonderful. Three and one-fourth million tons of ammonia is the 1956 production estimate, and this is backed up by a capacity of over 4 million tons. This capacity represents a 100 percent increase within a span of approximately four years.

Many have pointed with pride and viewed with alarm the rapid growth of ammonia as a petrochemical. The development is a natural one, because the newer refining processes produce large quantities of by-product hydrogen and refiners are faced with the problem of its economic utilization. They can burn the hydrogen as fuel, sell it to the chemical industry, or go into the petrochemical business. At the present time 85 percent of ammonia production uses hydrogen from petroleum sources and nearly all the new ammonia plants are located in conjunction with this source of hydrogen. Obviously many petroleum companies have gone into the ammonia business.

Where does the ammonia go? Three out of every four tons go to agricultural end-uses. The farmer has always been a capricious buyer, and the expanded use of ammonia in organic chemistry must serve as a buffer to the fluctuations in agricultural demands.

A recent REFINER article on Nitrogen Compounds from Petroleum [35(8), 147, 1956 (August)] noted that there are many hundreds of nitrogen-containing compounds which are derived either directly or indirectly from petroleum hydrocarbons. The article discussed the primary petrochemicals obtained by a reaction between ammonia or nitric acid (from ammonia) and a hydrocarbon. These compounds are hydrogen cyanide, acrylonitrile, nitroparaffins and aromatic nitro compounds.

Ammonia will react with various functional groups in organic compounds, and these reactions are used to produce a number of derivatives which are at least kissin' kin to a petrochemical and they utilize an appreciable amount of ammonia. Some of the more important of these compounds are shown in Figure 1.

Ammonia derivatives of compounds with functional groups may be formed by the addition of ammonia to the group followed by the splitting out of a small molecule (I), by simple addition of ammonia (II) or by double decomposition (III).

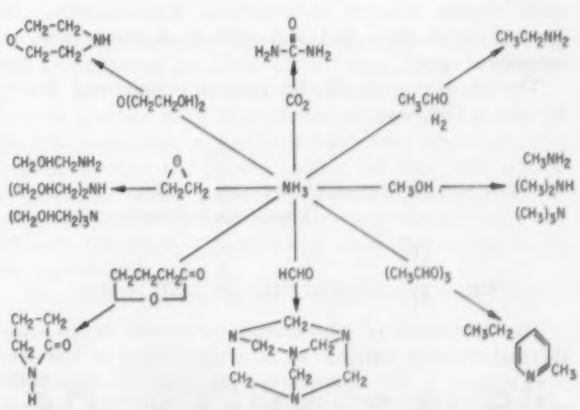



**FIGURE 1—Some of the principal types of organic compounds obtainable from ammonia.**

## These Petrochemicals Use Ammonia . . .

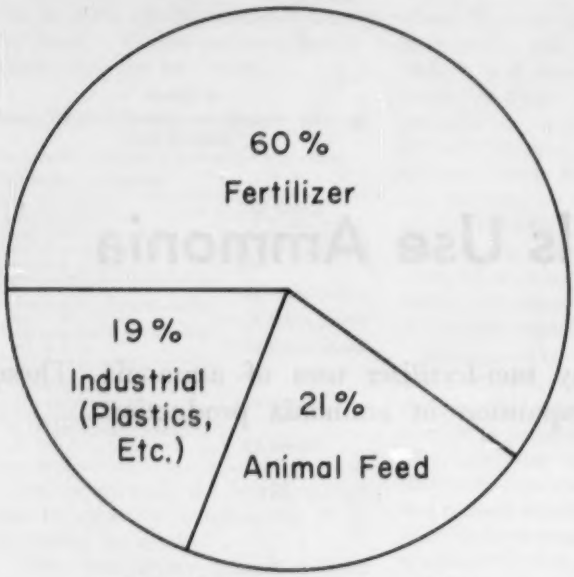



FIGURE 2—U. S. consumption pattern for Urea.

$$\text{I. } 2NH_3 + CO_2 \rightarrow H_2N - \overset{\overset{O}{\|}}{C} - NH_2 + H_2O$$

$$\text{II. } NH_3 + \underset{\diagdown\diagup}{\overset{O}{}}CH_2CH_2 \rightarrow HOCH_2CH_2NH_2$$

$$\text{III. } 2NH_3 + CH_3Cl \rightarrow CH_3NH_2 + NH_4Cl$$

All three of these types of reactions and modifications of them are used in industry.

### Urea

The synthesis of urea (carbamide) from ammonium cyanate in 1828 by Friedrich Wöhler is usually taken as the birth of organic chemistry. Today urea is one of the fastest growing ammonia derivatives with a 1956 production capacity estimated to be over 600,000 tons. This represents a significant portion of the U. S. synthetic ammonia production being used for urea production. Essentially all urea plants are operated in conjunction with captive sources of ammonia. Economically, the production of urea and ammonia is as inseparable as scrambled eggs.

The chemistry of all the present commercial routes to urea is identical.

$$CO_2 + 2NH_3 \rightleftharpoons NH_2 - \overset{\overset{O}{\|}}{C} - ONH_4$$

Ammonium carbamate

$$NH_2 - \overset{\overset{O}{\|}}{C} - ONH_4 \rightleftharpoons NH_2 - \overset{\overset{O}{\|}}{C} - NH_2 + H_2O$$

The formation of ammonium carbamate is an exothermal reaction carried out in a silver, lead or stainless steel reactor in the temperature range of 175 to 210 C. and under about 200 atmospheres pressure. One process (Du Pont) uses 400 atmospheres pressure. The ammonia-carbon dioxide ratio must be at least 2 to 1 and may be as high as 6 to 1 (Chemico). Two processes (Du Pont, Montecatini) also introduce water into the reactor. The reaction must take place in the liquid phase, and the reaction mixture is highly corrosive. Carbon dioxide conversions are between 50 and 88 percent.

About half of the ammonium carbamate is in equilibrium with urea and water. A reduction in pressure in a "decomposer" causes decomposition of the carbamate without affecting the urea. The ammonia and carbon dioxide are removed and may be recycled to the system or the ammonia may be recovered by conversion to a derivative such as ammonium sulfate. The urea is obtained by concentration, filtration and crystallization.

The three major uses of urea are given in Figure 2. The assured future of urea is in the fertilizer field, but, with a lower price indicated by sharply increased production, there will undoubtedly be an increase in the use of urea in feeds. Urea permits the use of cheaper, low protein carbohydrate feeds.

The major portion of the industrial utilization of urea is in the formation of urea-formaldehyde resins. Originally this type of resin was used predominately in the production of bottle closures, buttons, electric plugs and similar small items. Urea-formaldehyde resins are now used to make adhesives, finishes, molding compositions (especially radio cabinets), to improve crush and crease resistance in textiles and to impart wet strength to paper and paper coatings. Approximately 55,000 tons of urea was used in plastic production in 1955.

Of more direct interest to the petroleum industry is the use of urea in petroleum treating to separate straight-chain hydrocarbons from other types through extractive crystallization. Standard Oil Company (Indiana) is building a plant for the dewaxing of lubricating oils by this process. It depends on the straight-chain hydrocarbons in the oil uniting with the urea at room temperature to form solid adducts that can be separated by filtration. Extractive crystallization with urea also shows promise for jet fuel refining.

Urea finds many other uses in cosmetics, detergents and pharmaceuticals.

### Amines

**Ammonolysis** is the term used for the process of forming amines by the action of ammonia. Ammonolysis reactions may involve a double decomposition (Reaction III) or simple addition (Reaction II). When an ammonia-hydrogen mixture is used in the presence of a hydrogenation catalyst, the reaction is called *hydroammonolysis*. Both ammonolysis and hydroammonolysis are used industrially.

In ammonolysis reactions the ammonia may be used in the gas phase, as liquid ammonia or as a solution in water or an organic solvent. The choice will be determined by the temperature and pressure required to cause the reaction to take place, type of catalyst (if any), stability and solubility of the organic reactant and the possibility of side reactions such as hydrolysis and the formation of di- and triamines.

Aqueous ammonia is the most widely used reagent for liquid phase ammonolysis.

$$NH_3 + H_2O \rightleftharpoons [NH_4OH] \rightleftharpoons NH_4^+ + OH^-$$

The ammonolysis reaction is brought about by $NH_3$

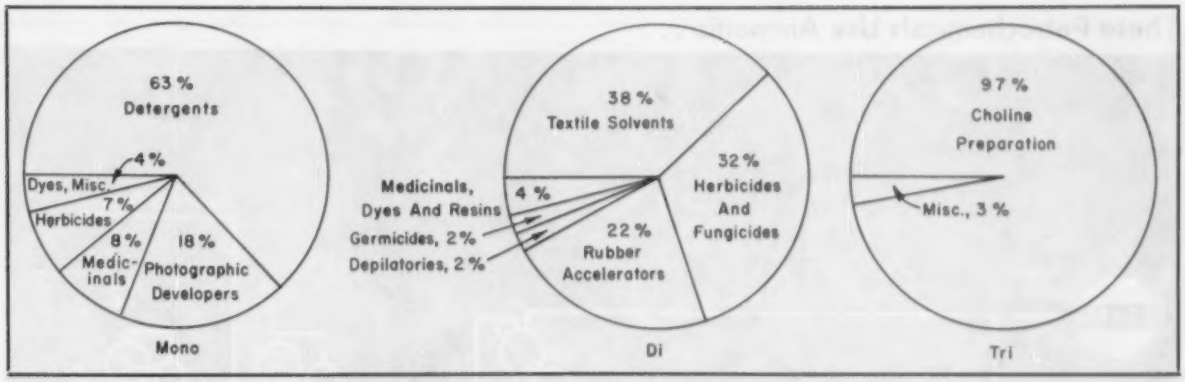



**FIGURE 3—Use distribution of the methylamines, mono, di, and tri (1954).**

and not $NH_4OH$. The ammonia concentration will usually range between 25 and 50 weight percent and operating temperatures will be above 100 C. Aqueous ammonia has the advantage of ease of handling and general applicability but has the disadvantage of limited solubility for chloro compounds and will cause some hydrolysis.

Alkyl chlorides are readily converted to alkylamines using aqueous ammonia. The resulting mono- di- and triamines are separated by utilizing differences in physical or chemical properties. The ratio of ammonia to the alkyl chloride will determine, to a large extent, the ratio of the three amines. Industrially, the ammonia ratio will be set by the purity of the product desired, yield, reaction time, expense of ammonia recovery and the ability to utilize the three types of amines.

Three different reactions are commercially available for the production of alkylamines from oxygen containing compounds: (IV) ammonolysis of alcohols over alumina catalyst, (V) hydroammonolysis of alcohols over hydrogenation catalysts and (VI) hydroammonolysis of aldehydes, ketones and carboxylic acids.

$$\text{IV. } ROH \xrightarrow{NH_3} RNH_2 + R_2NH + R_3N$$

$$\text{V. } RCH_2OH + NH_3 \xrightarrow[\text{cat.}]{\text{Ni}} RCN \xrightarrow[\text{Ni cat.}]{H_2} RCH_2NH_2$$

$$\text{VI. } RCHO + NH_3 \rightarrow \underset{|}{\overset{OH}{}}RCHNH_2 \rightarrow RCH=NH \xrightarrow[\substack{NiS-WoS_2\\ \text{catalyst}}]{H_2} RCH_2NH_2$$

All three processes yield a mixture of mono- di- and triamines. Methyl and *n*-propylamines are prepared from the corresponding alcohols, ethylamines are obtained from either ethyl alcohol or acetaldehyde, while isopropylamines and the butylamines are synthesized from acetone and butryaldehyde by hydroammonolysis. The lower alkylamines are produced by continuous vapor-phase reactions while both liquid- and vapor-phase reactions are used for the higher molecular weight amines.

Ammonolysis in an inert solvent is not extensively used because of the restricted solubility of ammonia in organic solvents, and many solvents (alcohols, for example) are not inert. The solubility of ammonia in halo compounds at room temperature is usually less than 1 percent.

**Methylamines.** The methylamines are produced by the vapor-phase ammonolysis of methyl alcohol over an alumina catalyst at about 450 C. and 10 to 50 atmospheres pressure. The annual production is about 20 million pounds with dimethylamine accounting for 70 percent of this figure. All three amines are simultaneously produced; thus the large demand for only one isomer presents a serious problem. The monomethylamine is generally recycled and the trimethylamine may be burned. Obviously this is not a satisfactory solution to the problem.

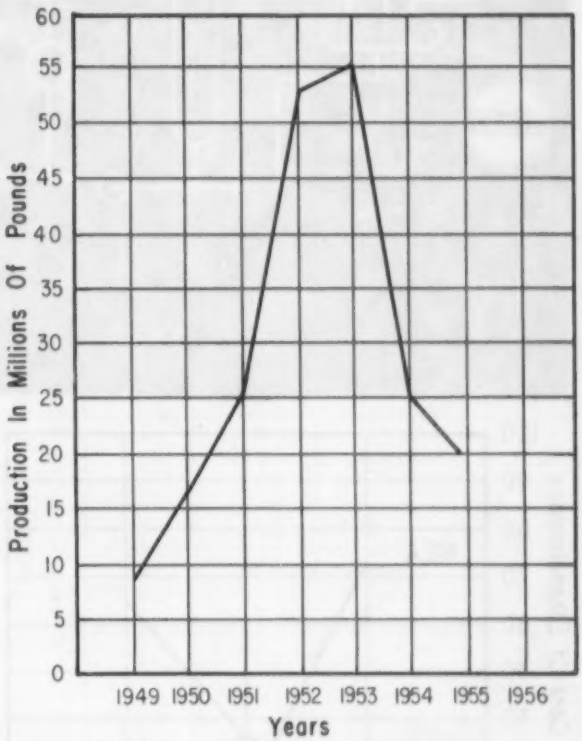



**FIGURE 4—Production of hexamethylenetetramine.**

The methylamines are low cost sources of basic organic

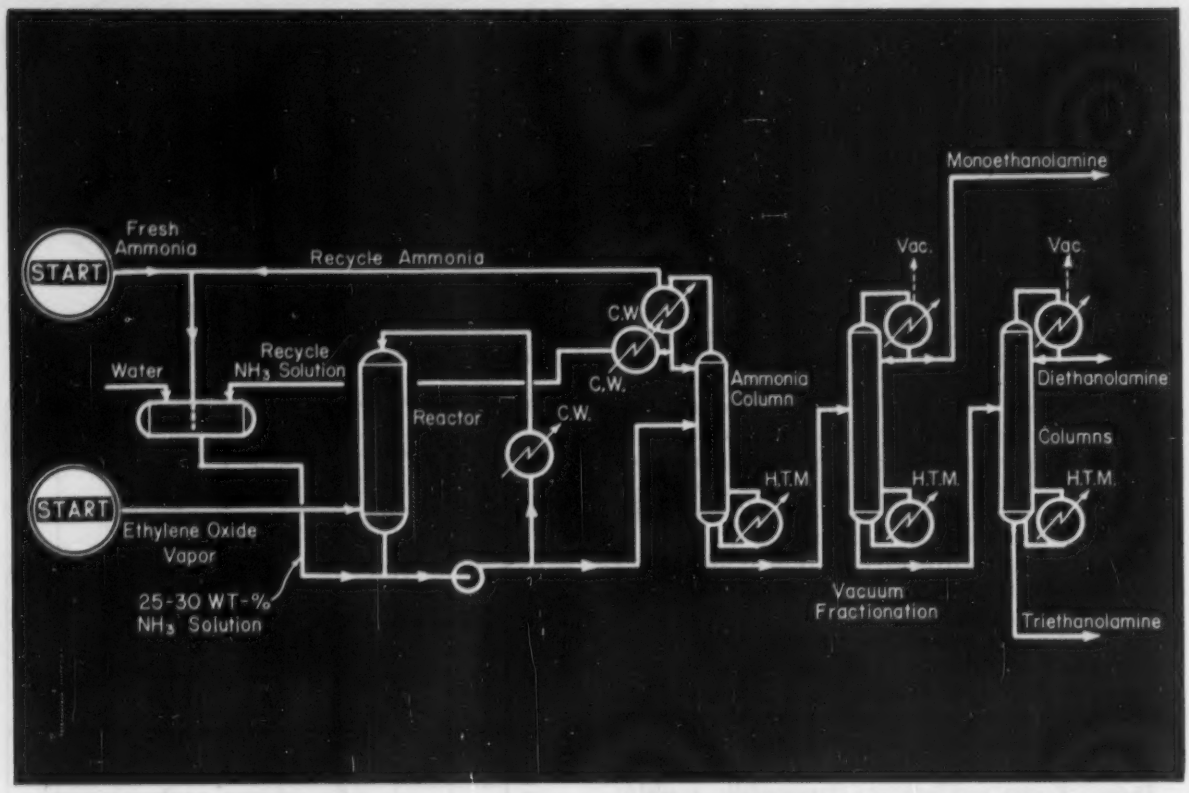



FIGURE 5—Flow diagram of a process for ethanolamine production.

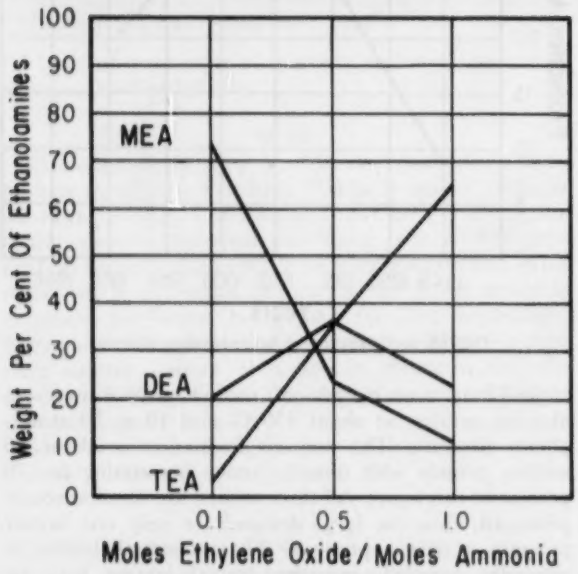



FIGURE 6—Effect of ethylene oxide-ammonia ratio on distribution of ethanolamines.

nitrogen. A broad definition of a base is any compound which will furnish a seat (an electron pair) for a proton. The two free electrons of the nitrogen atom serve this purpose. The basic nature of the methylamines is reflected in their use patterns (Figure 3). They are used as intermediates for rubber-vulcanization accelerators, pesticides, quaternary disinfectants, pharmaceuticals, photographic developers, dyestuffs and wetting agents. Choline, produced from trimethylamine, is used as a feed supplement, especially in poultry feeds.

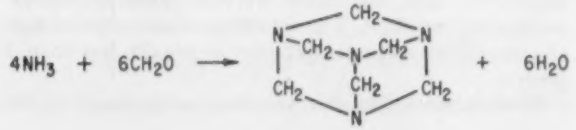
Approximately 45 percent of the methylamine production is captive.

**Other alkylamines.** The other low molecular weight alkylamines are obtained by the vapor-phase hydroammonolysis of aldehydes, ketones and fatty acids. The aldehydes and ketones require a temperature of about 320 C. and a pressure of 200 atmospheres with a nickel sulfide-tungsten sulfide catalyst; fatty acids require the same conditions, but a nickel, tungsten and molybdenum sulfide catalyst is used. A large excess of both ammonia and hydrogen is required and this excess is recycled.

The uses of the lower molecular weight alkylamines are similar to those of mono- di- and trimethylamine. Some of the newer uses include synthesis of ion-exchange resins, germicides, flotation agents, petroleum emulsion-breakers, gasoline additives, and catalysts. One of the more important uses of trimethylamine is in solubilizing of 2,4-D.

All of the lower molecular weight alkylamines are basic and have a characteristic ammonia odor.

**Hexamethylenetetramine.** The production of hexamethylenetetramine represents a special type of reaction between ammonia and an aldehyde.



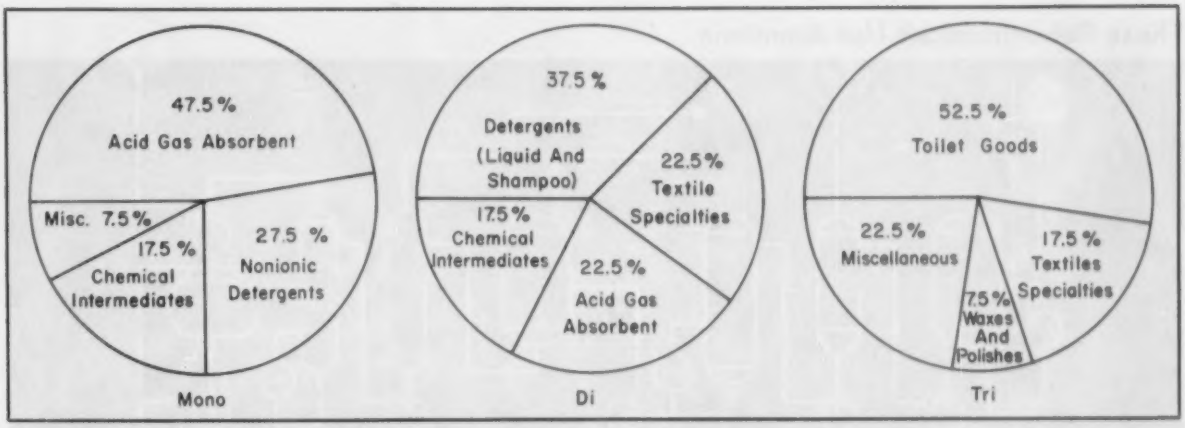



**FIGURE 7—Consumption pattern of the ethanolamines, mono, di, tri (1955).**

The reaction goes readily when 30 percent formaldehyde is mixed with 27 percent ammonia. The reaction is exothermal, and the temperature rises to about 100 C.

Hexamethylenetetramine is a versatile compound which is used in the production of drugs, fuel tablets, plastics, cork products, decay-resisting oranges and chloromycetin. The nitration of hexamethylenetetramine produces Cyclonite (**RDX**) and this use is reflected in the production figures given in Figure 4.

**Ethanolamines.** Ammonia adds readily to organic oxides to produce a mixture of mono- di- and trialkanolamines. Ethanolamines are produced by the reaction between ethylene oxide and 25 to 30 weight percent aqueous ammonia at 30 to 40 C and 10 to 20 pounds per square inch gage. The reaction is exothermal and cooling is required. Figure 5 gives a flow diagram of a typical process.

Ethylene oxide reacts faster with mono- and diethanolamine than it does with ammonia, thus the ethylene oxide-ammonia ratio is of considerable importance in determining the ratio of the three ethanolamines (Figure 6). The ratio may vary from 0.1 to 2.0 moles of ethylene oxide per mole of ammonia but is usually maintained between 0.3 and 0.6. The conversion of oxide is essentially complete, and the yield of amines is about 95 percent.

Use distribution of the ethanolamines is given in Figure 7. The general trend of use and production (Figure 8) has been sharply upward, but the relative importance of the three amines has changed markedly in the last several years. The increased use of diethanolamine in detergents generally and in the nonionic type detergents specifically has accounted for diethanolamine displacing monoethanolamine from first place. The most important refinery and gas producer use of monoethanolamine is in the scrubbing of hydrogen sulfide. About 90 percent of the gas scrubbers use monoethanolamine, and the use will increase as the use of natural gas increases. The present trend in hydrogen purification is to absorb the carbon dioxide in monoethanolamine from which it is readily recovered.

Monoethanolamine is also used to make dimethylaminoethanol [$(CH_3)_2NCH_2CH_2OH$] which is used to produce fugitive emulsifier amine soaps, volatile boiler water corrosion inhibitors, intermediates for ion exchange resins, lube oil additives and rust preventatives in hydrocarbon and aqueous systems.

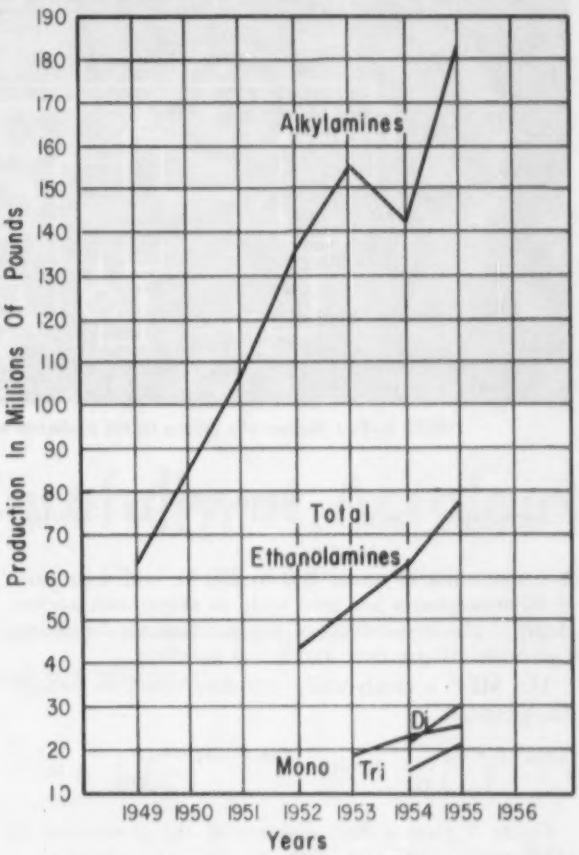



**FIGURE 8—Production of alkylamines and ethanolamines.**

### Methylvinylpyridine

The first step in the production of methylvinylpyridine (**MVP**) is the liquid-phase reaction between paraldehyde and an excess of ammonia to produce methylethylpyridine (**MEP**).

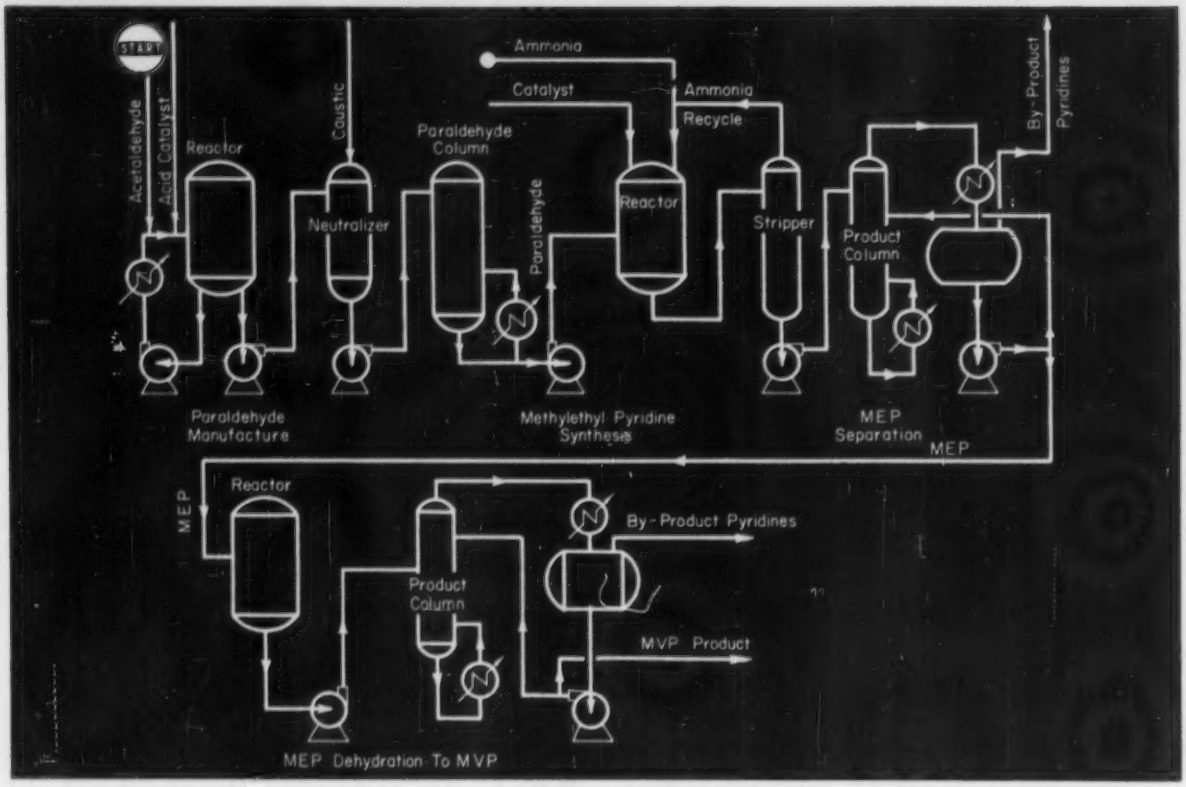



**FIGURE 9—Flow diagram of a process for the production of methylvinylpyridine (MVP) from paraldehyde and ammonia.**

$$4(CH_3CHO)_3 + 3NH_3 \rightarrow 3\ \text{(CH}_3\text{CH}_2\text{-pyridine)} + 12H_2O$$

A temperature of about 200 to 250 C. and a pressure of 50 atmospheres are used with an ammonium acetate catalyst. The by-products of this reaction are 2-picoline, 4-picoline (10 percent) and heavy pyridines.

The **MEP** is catalytically dehydrogenated to methylvinylpyridine.

$$\text{(CH}_3\text{CH}_2\text{-pyridine)} \xrightarrow{\text{catalyst}} \text{(CH}_2\text{=CH-pyridine)} + H_2$$

Figure 9 gives a flow diagram of the production of **MVP** from paraldehyde and ammonia.

Methylethylpyridine is used as an intermediate for nicotinic acid, for the synthesis of pharmaceuticals, and for the production of methylvinylpyridine. Methylvinylpyridine is used in the high polymer field.

### Vinylpyrrolidone

Vinylpyrrolidone is an ammonia derivative which is currently of interest in the textile fiber industry. It is produced by the ammonolysis of butyrolactone (from acetylene) to yield 2-pyrrolidone which is vinylated with acetylene.

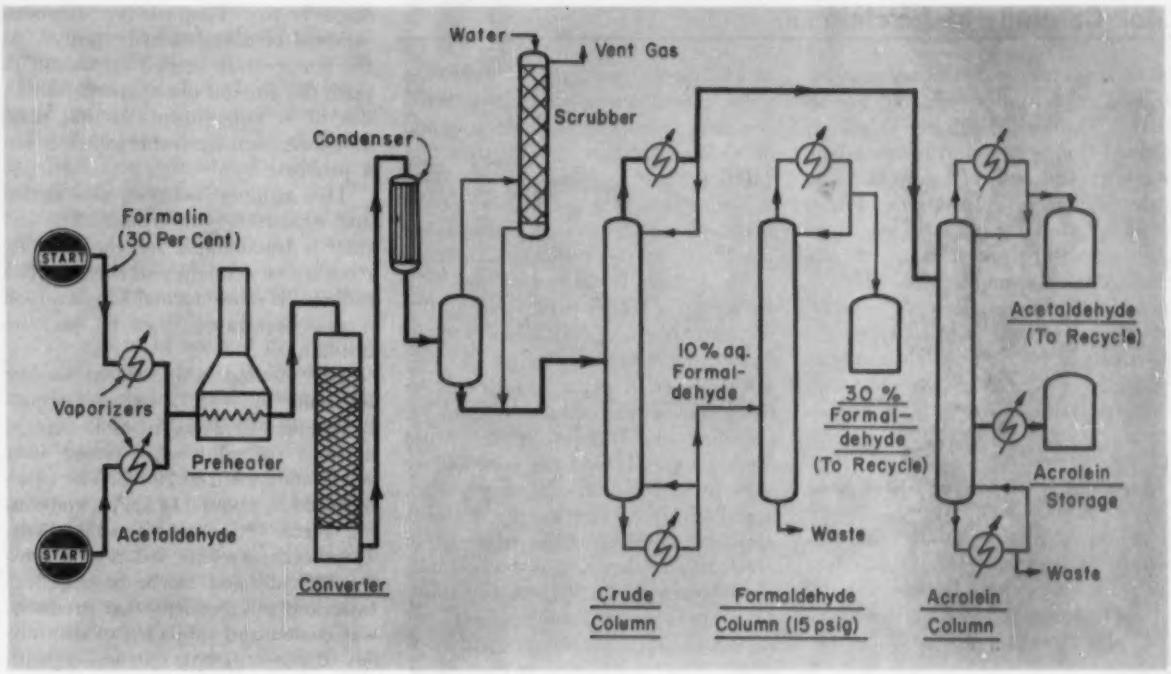
$$CH_2CH_2CH_2C(=O)\text{-}O + NH_3 \rightarrow CH_2CH_2CH_2C(=O)\text{-}NH + H_2O$$

$$CH_2CH_2CH_2C(=O)\text{-}NH + HC\equiv CH \rightarrow \text{N-vinyl-2-pyrrolidone}$$

Vinylpyrrolidone can be homopolymerized in bulk, solution or suspension in the presence of light or peroxide catalyst to give polyvinylpyrrolidone (**PVP**). The polymerization is best carried out in aqueous solution with hydrogen peroxide as the catalyst and a small amount of an amine or ammonia as an activator. Polyvinylpyrrolidone was originally noted as a blood volume expander, but at present it is finding increasing use in agriculture, cosmetics and pharmaceuticals.

Vinylpyrrolidone will copolymerize with almost all vinyl monomers, and it has been used to give control of hydrophobic and hydrophilic properties of polymers. One of the most recent synthetic fibers, Zefran, is reported to be a polymer of vinylpyrrolidone or a copolymer with acrylonitrile. There is also the possibility that the polymer contains methyl acrylate as a third component.

The few examples of the chemical utilization of ammonia given here serve to illustrate the great potential of ammonia in synthetic organic chemistry. These and many other chemicals will go far in justifying the current rapid expansion in ammonia production. ##




Synthesis of acrolein from acetaldehyde and formaldehyde.

Petrochemicals 56

# Look Carefully at Acrolein

**Here are two processes for making this newest commercial petrochemical. The problems and advantages of each method are discussed.**

**Peter W. Sherwood**
White Plains, N. Y.

FOR ACROLEIN's markets, the incubation period is just about over, as new technical developments promise to make this aldehyde a leading intermediate in petrochemical synthesis.

Probably the most important contribution comes from the new glycerin synthesis process, which underlies Shell Chemical Company's plant now under construction at Norco, La. In the route which is probably employed, acrolein is reacted with isopropyl alcohol to yield allyl alcohol. This, in turn, is converted to glycerine by reaction with hydrogen peroxide.

Another acrolein derivative, which has already staked out a market as poultry feed additive, is methionine. While this product is significant in dollar value, it is not a significant factor in the acrolein volume that we may soon expect for other uses.

The importance of acrolein rests in its high reactivity which offers a large variety of derivatives. Among those already on the market are acrolein dimer, hexanetriol-1,2,6 trimethylene glycol, glutaraldehyde. New possibilities for acrolein plus its derivatives are seen in the manufacture of polyurethanes, polyester resins, amino acids, various textile chemicals and plasticizers.

Acrolein was commercially introduced in 1946. Today, there are two U. S. producers in the field—Carbide and Carbon Chemicals Company and Shell Chemical Company, which is just now constructing its commercial acrolein plant in conjunction with its new synthetic glycerine unit.

It is interesting that the two manufacturers take wholly different routes to acrolein. Carbide, at its Institute

plant, relies on the condensation-dehydration of formaldehyde and acetaldehyde—both of which are ultimately derived from petroleum hydrocarbon. Shell, on the other hand, looks to direct oxidation of propylene for its acrolein production. Both of these processes will be discussed in some detail. (A third manufacturing method, involving decomposition of diallyl ether was piloted by Shell Chemical Company at its Houston plant. Other syntheses—e.g., treating glycerine with sodium bisulfate—are only of historical or laboratory interest).

**Acrolein from Lower Aldehydes**—The aldol condensation, classical route for the production of such compounds as acetaldol (and its derivative, n-butanol) may be used for the production of acrolein from formaldehyde plus acetaldehyde:

$$\underset{\text{Formaldehyde}}{HCHO} + \underset{\text{acetaldehyde}}{CH_3CHO} \rightarrow H_2C(OH) - CH_2 - CHO \rightarrow \underset{\text{acrolein}}{H_2C=CH-CHO} + H_2O \quad (1)$$

The unstable intermediate hydracylaldehyde is not isolated.

**Reaction Conditions and Catalyst**—The reaction is carried out in the vapor phase at substantially atmospheric pressure. Of numerous catalysts which have been investigated, silical gel impregnated with 10 percent sodium silicate is found[1] to be the most effective (initial activity of alkali-*free* silica gel is satisfactory but this catalyst loses its activity rapidly and is practically useless after one hour on stream). The alkali-impregnated silica gel catalyst shows almost no loss of activity at the end of 150 hours. It may be regenerated by the action of steam-diluted air at 500-550 C.

Stream temperature is 280-320 C. The feed consists of acetaldehyde and 30 percent formalin which are joined just preceding the fixed-bed reactor. Since the aldolization reaction is exothermic, means must be provided to abstract the heat of reaction; an increase in temperature favors the formation of by-products.

This reaction is not very sensitive to ratio of the two aldehydes in the feed,[1] and this is taken at or near the stoichiometric value 1:1. For best yield, incomplete conversion is taken per pass. Schulz reports a conversion of 50-52 percent on formaldehyde and 44-46 percent on acetaldehyde. This is achieved at a space velocity of 3.5 moles acetaldehyde per liter catalyst per hour. At this condition, the ultimate acrolein yield (after losses in recovery) is 72-75 percent of theory on formaldehyde and 79-82 percent on acetaldehyde.

The reaction make is subjected to fractionation in a primary column for overhead removal of acrolein and acetaldehyde. These light products are split in a secondary column. Here, acetaldehyde is taken overhead and is recycled to the reaction stage while acrolein, concentrated in the bottoms, is subjected to further fractionation. To prevent polymerization of acrolein in the primary, secondary, and final purification columns, an inhibitor (hydroquinone) is added to the system.

The bottoms of the primary column is a 10 percent aqueous solution of formaldehyde. This stream must be raised to recycle concentration of 30-37 percent. Formaldehyde exhibits a strong tendency to enter into polymerization and other undesired side reactions and therefore poses a serious concentrating problem. Schulz and Wagner[1] found it possible to carry out the enriching step satisfactorily by operating a plate column at 15 pounds per square inch gage, taking the 30 plus percent formalin overhead.

A look at the yield figures cited above shows that formaldehyde loss is more extensive than that of acetaldehyde. Much of this formaldehyde destruction occurs in the recovery stage. Stanley[2] finds that acrolein recovery in a simple series of fractionating columns (as described above) is beset with difficulties due to the formation of solid formaldehyde polymer which deposits in the distillation columns' condenser system and causes pluggage which gives occasion to frequent shutdowns.

To overcome this difficulty, Stanley extracts acrolein from the water phase by means of an organic solvent (xylene), retaining formaldehyde in the aqueous raffinate. In the process, the crude product from the reaction stage is first distilled for overhead removal of acetalydehyde (only). At the temperature needed for this stripping, the amount of vaporized formaldehyde is insignificant, so that polymer formation from this source is not a problem.

The stripper bottoms are cooled and extracted with xylene. The extract is fractionated for the separate recovery of acrolein and solvent. The raffinate is dilute formaldehyde which is re-concentrated (e.g., by pressure distillation).

The method is illustrated by the following run: 48.75 kg/hour acetaldehyde and 98.25 kg/hr of 35 percent aqueous formalin were passed over solid catalyst at 280-290 C. The eqeous residue, about 114 kg/hr, containing some 19 percent formaldehyde, 18 percent acrolein, 1-2 percent crotonaldehyde and traces of acetaldehyde and oily condensation products, was cooled and subjected to continuous countercurrent extraction with about 70 kg/hr xylene in an 8-stage extraction system. The recovered raffinate (aqueous phase) contained 0.3 percent acrolein and was substantially free of crotonaldehyde, and higher condensation products. It consisted almost exclusively of aqueous formalin, suitable for reconcentration to 30 percent strength.

The separated xylene, containing 98 percent of the acrolein initially present in the aqueous phase, was finally fractionated to yield first acrolein, and then crotonaldehyde. The xylene was cooled and recycled to the extraction process.

**Acrolein from Propylene**—The directed air oxidation of propylene is a naturally attractive approach to acrolein manufacture. This process is now of commercial significance, thanks largely to the solution of technical difficulties in three areas:

- Reaction conditions and catalyst;
- Removal of acrolein from reactor gases by absorption;
- Recovery of acrolein from the crude absorber liquor.

**Reaction Conditions and Catalyst**—Underlying the direct route to acrolein is equation (2):

$$CH_2=CH-CH_3 + O_2 \rightarrow CH_2=CH-CHO + H_2O \quad (2)$$

Three catalyst systems direct this reaction to acrolein in commercially

attractive yield: supported cuprous oxide, supported selenides of silver or copper, and supported cupric oxide. Certain benefits are seen in the use of some promoters, incorporated into the catalyst or brought in with the gaseous feed (e.g., elemental chlorine or organic chlorides).

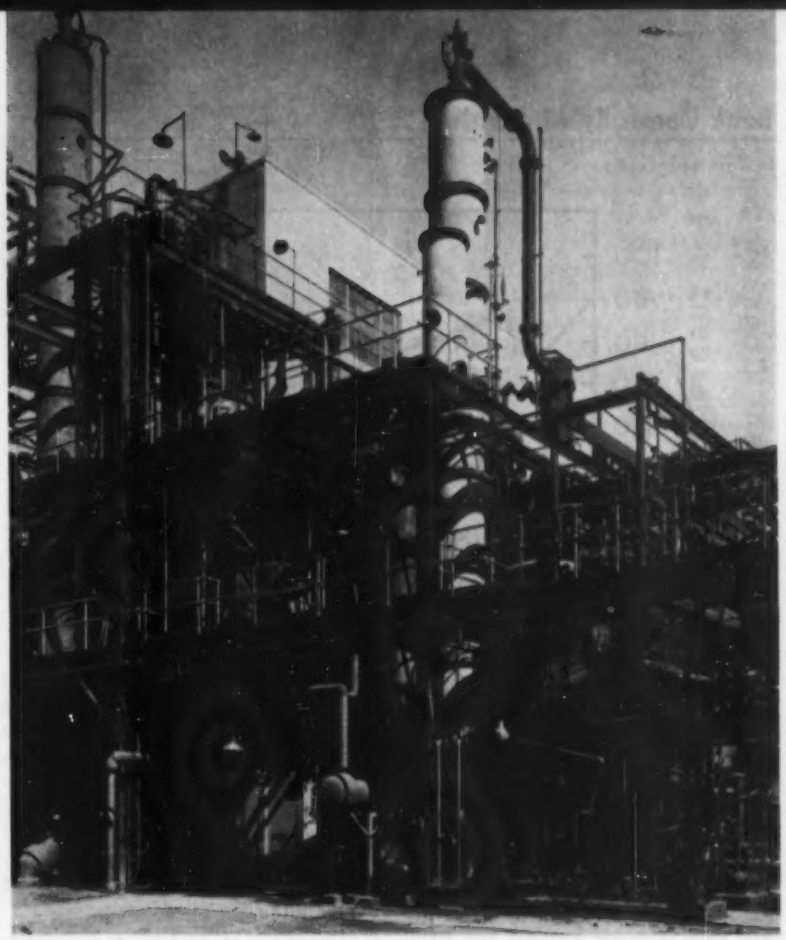
Supported cuprous oxide catalyst is made by impregnating the carrier with copper nitrate. This is decomposed, by heating the dried carrier between about 250 C. and 400 C. in a slow stream of air and then reducing the cupric oxide so formed to cuprous oxide by means of hydrogen.[3]

The choice of catalyst support is critical. Hearne[3] cites acrolein yields of 63-86 percent for propylene oxidation over cuprous oxide on silicon carbide versus only 27 percent when pumice serves as carrier. This catalyst system, with copper in its lower valence state, contains approximately 1 percent of the metal.

An alternate copper catalyst, developed by Stanard Oil Development Company[4] contains at least 2 percent of cu*pric* oxide on silica gel. This is the only one of numerous reported carriers which rendered a catalyst of reasonable selectivity (data on silicon carbide are not available in this connection). The supported cupric oxide catalyst must be activated between 590 C. and 760 C. Among possible promoters, cadmium oxide and barium oxide are mentioned.

The higher valence of the cupric oxide catalyst appears to offer an advantage of stability in the oxidative system of acrolein synthesis from propylene (negligible decrease in selectivity, small decrease in conversion after 17 stream days.) However, as we shall see below, suitable means are available to cope with the tendency of cu*prous* oxide to lose its activity at reaction conditions. Fairly high conversion is possible over the cupric oxide catalyst, though at only moderate selectivity.

Thus, the following results are reported[4] when a mixture of 90 volumes air and 10 volumes propylene is passed over Standard Oil Development's cu*pric* oxide on silica gel at the rate of 250 volumes feed per volume catalyst per hour. (See table below)



View of Carbide and Carbon Chemicals Company's Acrolein plant.

Shell's cu*prous* oxide catalyst permits effective operation over a wide range of conditions. The following ranges are preferred:[3]

| | |
|---|---|
| Oxygen concentration in reaction mixture prior to contact with the catalyst, volume percent | 4 to 8 |
| Mole ratio, propylene to oxygen | 4:1 to 10:1 |
| Balance of reaction mixture | Steam, or steam plus inert gases such as $N_2$, $CO_2$, propene, etc. |
| Apparent contact time, seconds | 0.1 to 2 |
| Temperature, C | 250 to 450 |
| Pressure, atmospheres | 1 to 10 |

| Percent CuO in Catalyst | Temp. of Activation, C | Reaction Temp., C | Conversion Mol Percent | Selectivity Mol Percent | Yield of Acrolein Per Pass | |
|---|---|---|---|---|---|---|
| | | | | | Mol Percent | Weight Percent |
| 10 | 677 | 308 | 47 | 41 | 20.4 | 27.2 |
| 2 | 760 | 302 | 58 | 42 | 24.2 | 32.2 |

The reactor is mounted in a fixed-bed reactor which must be provided with cooling facilities to handle the exothermic reaction heat. Off-gases are scrubbed by water or propylene (see below) for the removal of contained acrolein. Tail-gas leaving the scrubber is freed of carbon dioxide and the residual gas is partly recycled to the reactor for utilization of contained, unconverted propylene.

This recycling is made essential because only small conversion may be taken per pass. Its extent is controlled, above all, by the contact time allowed at a given level of catalyst activity. Available data point to a preferred per-pass conversion of 10-20 percent of the propylene. Oxygen consumption of 20-60 percent appears typical and depends, above all, on the feed ratio of reactants.

The process is illustrated by a run[3] in which a mixture of 7.8 volume per-

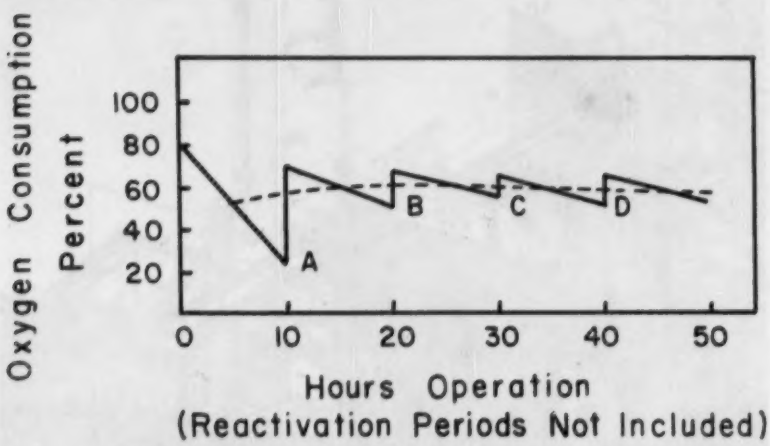



**FIGURE 1—Effect of regeneration on cuprous oxide catalyst activity.**

cent oxygen, 27.6 percent propylene, 35.3 percent steam and 29.3 percent nitrogen was passed at 22 psig over a catalyst containing 1.43 weight percent copper in the form of cuprous oxide supported on porous silicon carbide. Operating temperature was maintained at 348 C. At the apparent contact time of 0.8 second, about 24 percent of the oxygen reacted. The yield of crude acrolein was about 86 percent on the reacted propylene.

The addition of small amounts of organic chlorides to the gas feed is reported to cause a significant improvement in acrolein yield.[5] For one set of conditions (370 C, 1.06 percent copper as cuprous oxide on silicon carbide, propylene:oxygen ratio = 20:1; i.e., outside the optimum range), Hearne reports an acrolein yield of 69.6 percent on propylene in the presence of .032 mole percent HCl (based on propylene) versus 50.8 percent yield in the absence of chloride.

Product distribution is reported for another run, carried out at 421 C maximum temperature in the presence of 0.1 mole percent isopropyl chloride, and at conditions leading to 63 percent acrolein yield:

| | Yield, percent based on propylene consumed |
|---|---|
| Acrolein | 63.09 |
| Carbon dioxide | 18.73 |
| Saturated aldehydes | 10.54 |
| Carbon monoxide | 3.05 |
| Acid (as acetic acid) | 1.29 |
| Non-carbonylic compounds | 0.59 |
| Polymeric compounds | 0.10 |
| Unaccounted for | 2.61 |
| | 100.00 |

Improvement in selectivity due to lowered conversion per pass is achieved, above all, by reduction in carbon dioxide formation. But formation of undesired by-product carbonylic compounds is also reduced. Thus, at conditions providing a 73 percent acrolein yield, the total yield of carbonylic products is 81 percent of which 90 percent is acrolein.[6]

The make-up of the *organic* products will be dealt with in greater detail in our discussion of acrolein recovery and purification.

Over certain range of operating conditions, cuprous oxide shows pronounced loss of activity and selectivity after a few (10-15) hours on stream. Detling[6] reports that this catalyst may be easily reactivated by turning off the oxygen supply and continuing flow of the hydrocarbon stream at normal reaction temperature and pressure. After 15 minutes of such oxygen elimination, catalyst activity is reported to be restored. The effect is illustrated in Figure 1 for a catalyst containing about 1.4 percent cuprous oxide on silicon carbide.

Even beyond the fact of reactivation, this treatment reportedly raises catalyst stability. Thus, one instance is cited in which the fresh catalyst lost 50 percent of its initial activity after slightly over seven hours on stream. After the fourth reactivation treatment, the rate of decline in activity was such that about 30 hours would have been required for a 50 percent activity loss.

**Alternate Catalyst Systems**—The use of supported metal-selenium salts as catalyst for propylene oxidation has been reported by Distillers Company, Ltd.[7,8,9] These catalysts are reported to permit high conversion per pass with good selectivity.

Good initial activity is reported for silver selenite which has, however only a short useful life. Similarly copper selenide shows initially good activity and selectivity which, however, drops off very rapidly.

The loss in activity is traced to dissociation of the copper selenide at reaction conditions (300-350 C.). This tendency may be offset by introducing elemental selenium with the feed. This may be accomplished by passing a part of the incoming gases over elemental selenium which is partly vaporized thereby. Obviously, selenium must be recovered, nearly quantitatively, from the reactor make gases, and this requirement imposes a heavy burden on the process.

To illustrate the favorable effect catalyst pretreatment by selenium, Goodings cites the following results for the oxidation of propylene over copper oxide on *pumice*, at otherwise comparable conditions.

| | CuO untreated | CuO pretreated |
|---|---|---|
| Percent propylene converted to acrolein | 8.3 | 28.9 |
| Percent propylene converted to carbon dioxide | 4.2 | 14.5 |

(Note the improvement in activity, but nearly unchanged selectivity.)

In considering these results, the reader is reminded that choice of catalyst carrier is of critical importance for cupric oxide, untreated with selenium, and that the data of Standard Oil Development Company, which are cited above, indicate good activity for cupric oxide *only* when supported on silica gel.

For selenium-treated copper oxide, activated alumina is reported to be a particularly favorable carrier.

As is the case in conversion over cupric oxide-on-silica gel, a high oxygen:hydrocarbon ratio is called for by the selenium-treated copper oxide catalyst. Permissible propylene concentration in the feed gas is limited to 2 percent maximum in order to remain below the explosive limit. In conversion over selenium-treated copper oxide on alumina, initial oxygen

concentration is preferred above 10 percent.

Using Distillers Company's catalyst at 320 C. for a feed mixture consisting of 2 volume percent propylene, 20 percent oxygen, and 78 percent carbon dioxide, propylene was converted to acrolein with a per-pass conversion of 77 percent and an ultimate yield of 84 percent.

Yet another oxidation catalyst, which has been reported for acrolein synthesis, is tellurium oxide. Augustine[14] claims the oxidation of propylene to acrolein, over a catalyst consisting of tellurium oxides and in the presence of elemental chlorine. Reported per-pass conversion is only about 2.5 percent.

**Acrolein Recovery & Purification**—As we have seen, cuprous oxide catalyst, while starting with an initial propylene concentration of 25 to 30 percent, is restricted to a small (10 to 20 percent) conversion per pass. Other catalyst systems, which permit higher conversion, operate with an initial propylene content of only 2 percent.

Thus, in any case, the acrolein content of the reactor gas is quite low, normally in the range 1-3.5 weight percent. Its recovery introduces therefore a significant cost item.

Water scrubbing at pressure between 125 and 300 pounds per square inch absolute is a feasible method of acrolein recovery, though the degree of dilution in the reactor gas makes very high water rates necessary. The rich liquor leaving the absorber contains rarely more than 1.8 weight percent acrolein, and may be substantially more dilute.

Because of the needed high water rates, Cole[10] proposes the use of propylene as scrubbing medium for reactor gas which has been previously quenched and subjected to a light water wash.

Thus, the gases obtained by reacting propylene and air (propylene:$O_2$ ratio = 6.0) over cuprous oxide catalyst at 375 C., are introduced into the bottom of a quench tower. Water is fed to the column's top at 20-50 C. and the bottoms temperature is maintained at 80-100 C.

Liquid, aqueous bottoms containing formaldehyde are withdrawn from the base of the quench tower. The cooled effluent gases are taken overhead to an absorber column. This stream consists of about 30 moles carrier gas (propylene, carbon monoxide, carbon dioxide, nitrogen, oxygen) per mole of total carbonylic compounds (90 percent acrolein).

The absorber column is operated at 260 psia and 20 C., using as scrubbing medium either (a) liquefied propylene or (b) water. To obtain, at these conditions, 99.9 percent recovery of the gas stream's acrolein content, solvent:acrolein mole ratio is reported as follows: (a) Propylene—50.5 (leading to an absorbate of 2.6 weight percent acrolein content); (b) Water—176 (absorbate contains 1.7 weight percent acrolein).

Thus in the case of acrolein synthesis, propylene scrubbing appears to offer only slight advantage over absorption in water, probably not enough to pay for the additional costs inherent in propylene liquefaction and handling.

The problem of further isolation of acrolein therefore resolves to recovery from water, followed by final purification.

**Meet the Author**

PETER W. SHERWOOD, a frequent contributor to PETROLEUM REFINER is a member of Ethyl Corporation in New York. Previously, he held responsible positions with Blaw-Knox Company, and Koppers Company, Inc.

Sherwood received his undergraduate training and his M.S. degree in chemical engineering from Columbia University. In October 1945, he was invited to join the Technical Oil Mission to Germany and spent more than a year as assistant chief of the fuels and lubricants unit of Field Information Agency, Technical. While in this capacity, Sherwood had the opportunity to intimately study German synthetic and natural oil technology.

Sherwood's work and his many facets of wide technical experience have made him a leading authority in the field of petrochemical operations.

The aqueous solution, obtained in the scrubbing step, contains a complex mixture of organic compounds—predominantly carbonylic materials. The first step in their recovery is a stripping operation in which acrolein, along with other oxygenated light-boiling compounds is taken overhead.

Distillers Company[11] has found that this distillation is accompanied by considerable polymer formation, which causes yield loss and may obstruct the stripping column to the point of shutdown after as little as 3 to 4 days.

The trouble is ascribed to the presence of oxygen which is dissolved in the water. Such oxygen can, of course, be removed by heating briefly to a temperature near the liquor's boiling point. To accomplish this step without excessive polymerization, Distillers Company finds it necessary that the solution's pH be adjusted to a value between 6 and 7 (by adding sulfuric acid).

The oxygen is desorbed after a brief contact time (three minutes at or near the boiling point). The liquor may then be fed to the crude acrolein still, which is operated at substantially the same temperature as the aeration step. An inhibitor (hydroquinone) serves to prevent polymerization in the course of acrolein stripping. But for the aeration step, hydroquinone consumption would be excessive.

Crude acrolein, taken overhead by stripping from its aqueous solution is contaminated by other oxygenated organic compounds which must be removed to render the product saleable. Typically, crude composition will cover the following range:

| | | | | |
|---|---|---|---|---|
| Acrolein | 80 | to | 90 | weight percent |
| Acetaldehyde | 3 | to | 10 | |
| Propionaldehyde | 0.5 | to | 3 | |
| Acetone | 1.0 | to | 5 | |
| High boiling material | 1.0 | to | 2.0 | |
| Water | 2.4 | to | 6.0 | |

Purification of such a mixture by direct fractionation is not feasible, partly because of azeotrope formation (the acrolein-water azeotrope at atmospheric pressure contains 2.7 weight percent water), but mainly because of the low relative volatilities of propionaldehyde and acetone in relation to acrolein. (At atmospheric pressure,

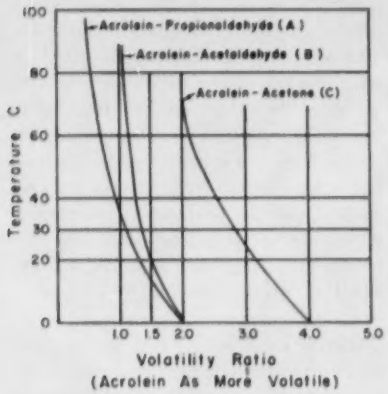



**FIGURE 2—Volatility ratio of propylene oxidation products in the presence of water.**

$\alpha_{acetone\text{-}acrolein} = 1.12$ and $\alpha_{acrolein\text{-}propionaldehyde} = 1.12$.)

Thus, while a direct separation from acetone plus propionaldehyde is possible, it calls for an excessive number of equilibrium stages and for at least two fractionation steps in series, thus imposing considerable purification cost. Furthermore, the recovered acrolein must still be dehydrated.

Pierotti[12] finds that addition of water has a marked widening effect on the relative volatilities involved, and that this effect becomes even more marked as the system temperature is lowered (by reducing distillation pressure). This effect is illustrated in Figure 2, which shows relative volatilities, *in the presence of water*, as a function of temperature.

Thus, the basis is given for a low-temperature extractive distillation system in which water serves as solvent. The solvent should be at least 80 weight percent of the total liquids in the distillation column.

With the reduction in operating temperature, the water content of the azeotropic acrolein-water mixture decreases, so that an overhead product can be obtained which assays only 0.4 weight percent moisture.

Figure 2 shows that the ease of separation improves markedly with decreasing temperature. Pierotti states that bottoms temperature should be below 35 C., but preferably below 20 C.

For efficient operation, a definite minimum contact time is stated to be necessary on each plate, possibly in order to complete hydrate formation with the saturated carbonylic compounds which constitute the heavy boilers in the extractive distillation system. This contact time is between 25 and 50 seconds, but Pierotti claims permissible reduction to 6 seconds by the addition of small amounts of phosphoric acid.

Table 1 illustrates performance in the extractive distillation of a typical crude acrolein mixture. This mixture was obtained by oxidation of propylene, followed by water scrubbing at 125 psig and finally by topping off a crude acrolein concentrate as previously described. Column 1 of Table 2 shows the crude acrolein feed on a water-free basis (water content was 3-6 percent).

The crude acrolein obtained in this manner was freed of acetaldehyde by fractionation. The resulting crude fractionator bottoms (having the composition shown in column 2 of Table 2) were subjected to low-temperature extractive distillation in the presence of water at the conditions shown in Table 1.

**TABLE 1**

| | |
|---|---|
| Column top temperature, C | —9.7 |
| Column bottom temperature, C | 16 |
| Column top pressure, mm. Hg abs. | 50 |
| Column bottom pressure, mm. Hg abs. | 152 |
| Water content of column precent by weight of total liquid on trays in column | 83 |
| Reflux ratio | 2 |

Columns 3 and 4 of Table 2 show the composition of acrolein product and the extent of its removal from the waste bottoms.

**TABLE 2**

| | Crude Acrolein Feed to Fractionation | Extractive Distillation | | |
|---|---|---|---|---|
| | | Feed Bottoms from Crude Fractionator | Overhead | Bottoms |
| | Weight Percent | Weight Percent | Weight Percent | Weight Percent |
| Acrolein | 90 | 95.7 | 99.4 | 0.10 |
| Propionaldehyde | 2.0 | 2.15 | 0.2 | 0.21 |
| Acetone | 2.0 | 2.15 | 0.0 | 0.23 |
| Acetaldehyde | 6.0 | 0.2 | 0.0 | .02 |
| Water | ..... | ..... | 0.4 | 99.46 |

An alternate method, which permits production of an even purer grade of acrolein and possible recovery of propionaldehyde, carries out the extractive distillation in two stages.[13] The first of these is operated in the presence of water at superatmospheric pressure (say, 15 psig) to yield an overhead product containing about 50 percent propionaldehyde and 50 percent acrolein. The bottoms are then distilled extractively as outlined above to yield acrolein in approximately 99.6 purity.

Thus, a basis is given for the production of acrolein of saleable quality and in good yield, starting from propylene. The purification problem in this synthesis is substantially more difficult than in the production of acrolein by the condensation of acetaldehyde with formaldehyde, since by-products in this classical route are essentially all of much higher boiling point than acrolein.

Each of the two successful commercial syntheses of acrolein has special points in its favor. The obvious attraction of direct propylene oxidation is the low cost of raw materials. The reaction may be carried out in yield above 80 percent. On the debit side is the requirement to operate at low conversion per pass (thus requiring large equipment per unit output), the need to recover acrolein from very dilute reactor gas, and the complexity of the product mixture which calls for special purification methods.

The classical route draws on more costly raw materials, but permits higher (approximately 50 percent) conversion per pass. The recovery and purification of acrolein does not offer a serious problem in this process. Formaldehyde reconcentration poses certain difficulties, but these exist in common with other manufacturing processes, and have long since found satisfactory solution.

Both syntheses are capable of producing high-purity acrolein to supply a market which promises significant expansion during the next few years.

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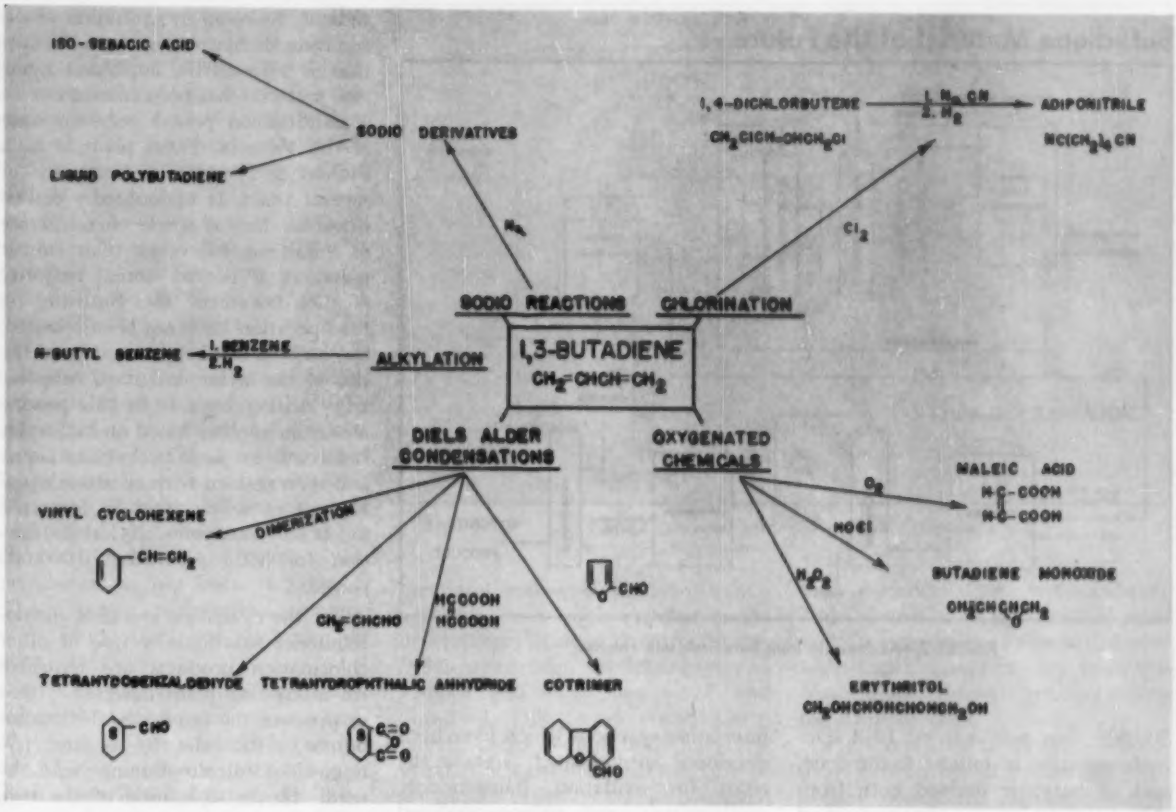


FIGURE 1—Butadiene derived petrochemicals.

# Growing Fast—Butadiene Material of the Future

**Here's what is being done with butadiene now. There seems no limit to its use as a starting material in petrochemical manufacture.**

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BUTADIENE, long established as the big volume raw material in the huge synthetic rubber industry, is coming into its own as a truly chemical raw material. Sparked by the broad expansion in manufacturing capacity for this versatile chemical now being installed, a growing group of interesting chemicals is joining the already well established adiponitrile in the family of commercial derivatives of butadiene. Isosebacic acids, Diels-Alder condensate with furfural and acrolein, and low molecular weight liquid polymers are available now from commercial plants, or from pilot plants while full scale facilities are being constructed. Tetrahydrophthalic anhydride, vinylcyclohexene, butadiene monoxide, butylbenzene, and erythritol, to name just a few others, have been offered in sample or pilot plant lots, and await only the development of markets, to proceed into production.

1,3-Butadiene was just emerging from the category of a laboratory curiosity before the start of World War II. Limited quantities had just reached the market, recovered from the by-products of hydrocarbon cracking and from butylene chlorination, an off-shoot of synthetic glycerine manufacture. Its practical conversion to synthetic rubber by emulsion polymerization was new. Driven by the necessity of manufacturing synthetic rubber on a large scale when our natural rubber was suddenly cut off, industry built under government auspices a butadiene producing capacity of approximately

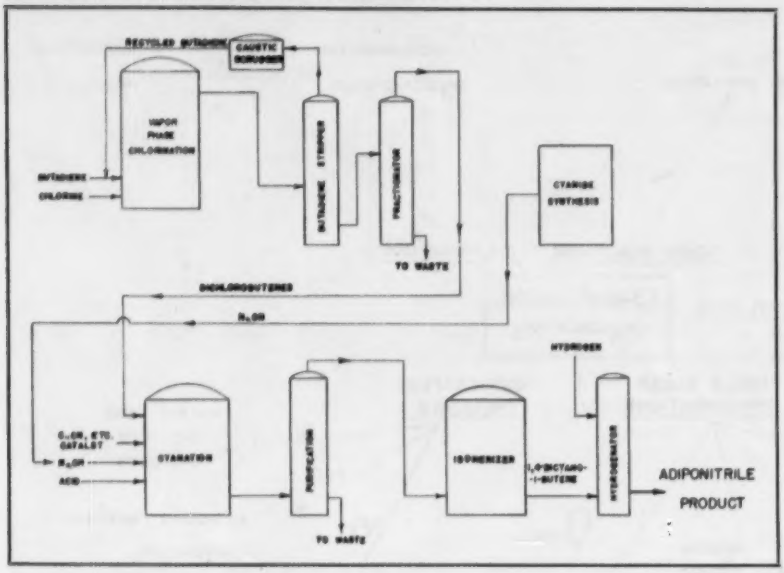


**FIGURE 2—Adiponitrile from butadiene and chlorine.**

500,000 tons per year by 1943. Dehydrogenation of butane to butylene, and of butylene derived both from this source and from refinery cracked gases, further to butadiene was the major route selected; but a large fraction was also based on catalytic conversion of ethanol. By April, 1955, when the government-owned plants were sold to private industry, capacity had increased to 860,000 tons per year, with the petroleum-based processes having largely supplanted those based on the more expensive alcohol raw material.[1] A steady stream of announcements of plant expansions and of new plants has followed. By June, 1956, expansions had been announced and new plants were under construction which would bring this to 1,100,000 tons of yearly capacity by 1958.[2, 3] While synthetic rubber and other high polymers have always consumed the lion's share of this (585,000 tons in 1954) and their continued growth leads to predictions of a consumption of 900,000 tons per year by 1958, it is evident there should be plenty of butadiene for the petrochemical manufacturer.

The butadiene molecule, with its two conjugated unsaturated linkages has offered an enticing target for the chemical researcher. This is evident from a consideration of the chart, Figure 1, in which some of the many interesting reactions which have been developed are indicated. Areas in the chart for oxidation, halogenation, condensation, and sodium-catalyzed reactions indicate general reaction types which have been applied to butadiene. Included in each section are one or more chemicals which have resulted. In this condensed chart we have shown only chemicals which have reached the market or for which commercialization plans are known to have been considered. There are dozens of others to be found in the technical and patent literature, of course; probably others are known and perhaps even receiving consideration for immediate development in the many industrial and academic laboratories active in the field.

Rather obviously absent from the chart, along with the standard synthetic rubber type polymers, are the other types of high polymers of butadiene which currently account for a good sized chunk of the butadiene consumption. High styrene copolymers for plastic shoe soles, etc., and the polymers used in the fast growing latex paint industry have had to be classed as synthetic rubbers, so that the scope of this article could be limited to the space available.

**Adiponitrile**—Chlorination of butadiene, followed by cyanation of the resulting dichlorobutenes, and reduction to adiponitrile, important nylon raw material, has been carried out on a multimillion pound per year basis at the Victoria, Texas plant of E. I. duPont de Nemours & Company for several years. It undoubtedly constitutes the largest single chemical use of butadiene for other than rubber polymers, if not an actual majority of such butadiene use. Statistics on the operation have not been released, but an idea can be obtained from the size of the nylon industry. Adiponitrile, arising both from this process and from another based on furfural is reduced to hexamethylenediamine and then reacted with an about equal amount of adipic acid to form the nylon salt monomer. Nylon production for 1953 reached 170,000,000 pounds.[4]

For the cyanation reaction, dichlorobutenes substantially free of other chlorination products are required. An interesting point however is that to produce the required 1,4-dicyanobutene, either the 1,4 or the 1,2-isomer of dichlorobutene may be used.[5] Hence separation of the two, which are both produced in the chlorination reaction in very substantial percentages, is not required, and the process is enormously simplified. Hydrocyanic acid, in reacting with the isomeric 1,2-dichlorobutene simultaneously causes a shift in the double bond position, and 1,4-dicyano-2-butene results.

Butadiene, purchased from various suppliers, is chlorinated in the first section of the Victoria plant. The reaction is characterized by high yields of the dichlorobutenes and nearly complete suppression of the substitution reactions. The success of the process is believed to result from the use of an initial reaction zone in which chlorine and butadiene are rapidly mixed for a short time at a relatively low temperature, before passing into the final reaction zone where the chlorination is completed at higher temperature.[6] The mol ratio of butadiene to chlorine is maintained high, generally well over 1 to 1. Both streams are preheated, and the reaction zone is maintained at about 175 C. The mixed reactants pass directly into the second, packed reaction zone when the temperature is allowed to rise to 250 C. This temperature however is below the level where substi-

tution reactions are appreciable. This reaction zone is much larger, so that a longer reaction time is allowed here. Since an excess of butadiene is used, conversion based on the hydrocarbon is low. The butadiene vapors are caustic washed, compressed and recycled.

In the subsequent steps of the process, the dichlorobutene mixture is cyanated by reaction with hydrogen cyanide in an acid medium, with a cuprous cyanide catalyst.[6,7]

The resulting solid 1,4-dicyano-2-butene is freed from chlorine-containing impurities[8] and at least partially isomerized to the liquid 1,4-dicyano-1-butene.[9,10] It is then hydrogenated to adiponitrile, the end product at Victoria. The use of an especially neutralized palladium catalyst to eliminate cyclization to cyano cyclopentene-imine has been indicated.[11] The process is conducted vapor phase with large excess of hydrogen at about 300 C.

At Victoria, the rather large waste stream of concentrated brine is handled in a unique manner. No wastes are allowed to flow into the adjacent Guadalupe River. Instead, the brine is treated and pumped into deep disposal wells.

The adiponitrile is shipped to Orange, Texas, where the conversion of butadiene into nylon is completed, by the further reduction of the adiponitrile to hexamethylene diamine and reaction of the latter with adipic acid from the Orange plant to give nylon salt.

**Sodium-Catalyzed Reactions**—One of the earliest ways known of effecting butadiene polymerization was by the use of sodium as a catalyst. Synthetic rubber was made in this way in Russia and Germany in the late '20s. The product was rather poor, however, and the reaction hard to control. In recent years, interest in this process has been renewed by the development of a process based on the use of fine dispersions of sodium.[12] In preparing these rubbery polymers of butadiene it was observed that under certain reaction conditions a low-molecular weight liquid polymer could be made, which had interesting properties as a drying oil. The marked expansions which have taken place in the sodium manufacturing capacity, and the developments which these manufacturers have pioneered in making sodium dispersions available, have given impetus to the development of these liquid polymers. Publications from the laboratories of Phillips Petroleum Company[13] and Standard Oil Development Company[14] indicate that both have developed processes for manufacture of the liquid polymers. This polymerization process is now being carried out in a semicommercial plant, using metallic sodium as the catalyst, by Phillips Petroleum Company. The product is marketed under the name Butarez liquid polybutadiene.

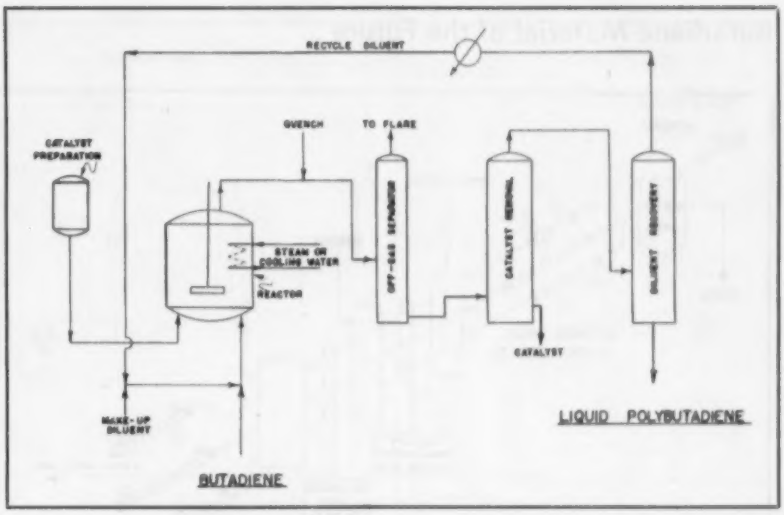


**FIGURE 3—Liquid polybutadiene from butadiene.**

This polymer is primarily a linear chain built up by random 1,4 and 1,2 addition during the polymerization reaction. The resulting product has many applications in the field of protective coatings. Spirit varnishes based on liquid polybutadiene can be air-dried to yield finishes of high gloss and hardness, or baked at elevated temperatures to produce tough, flexible films having excellent chemical resistance and thermal stability. It can also be used as an effective modifying agent for improving the bodying and drying characteristics of conventional oils and alkyds in oleoresinous coatings. The excellent electrical properties, high temperature stability, and chemical resistance of the thermally-cured polymer has made it useful in cast form as a machinable resin and as a bonding resin for a variety of laminate applications.

Liquid polybutadiene, being unsaturated, is adaptable to numerous chemical reactions, such as chlorination, hydrogenation, hydroxylation, and vulcanization. By chemical reaction, its properties can be varied over wide limits. Products vary from viscous liquids, through rubbery solids, to rosin-like solids.

The properties of liquid polybutadiene can be varied by changing operating conditions, but for commercial operation a good balance of desirable physical properties and process economics (i.e., yield and reaction rate) is obtained by carrying out the polymerization at a temperature of about 200 F. The pressure must be high enough to keep the unreacted butadiene in solution, normally 40 to 50 pounds per square inch gage. Properties of a typical liquid polybutadiene product are given in Table 1.

**TABLE 1**
**Typical Properties of Butarez* Liquid Polybutadiene**

| | |
|---|---|
| Color, Gardner | 10 |
| Molecular Weight, Approximate | 1500 |
| Viscosity, Centipoises, 100 F | 2500–5000 |
| Specific Gravity, $d_4^{20}$ | 0.91 |
| Double Bonds per C-4 Unit | 0.8 |
| Refractive Index, $n_D^{20}$ | 1.519 |
| Iodine Number, Approximate | 375 |

* A trademark of Phillips Petroleum Co.

A simplified flow diagram for a continuous liquid polybutadiene process as described in U. S. Patent 2,631,175 is shown in Figure 3. The butadiene is mixed with an inert hy-

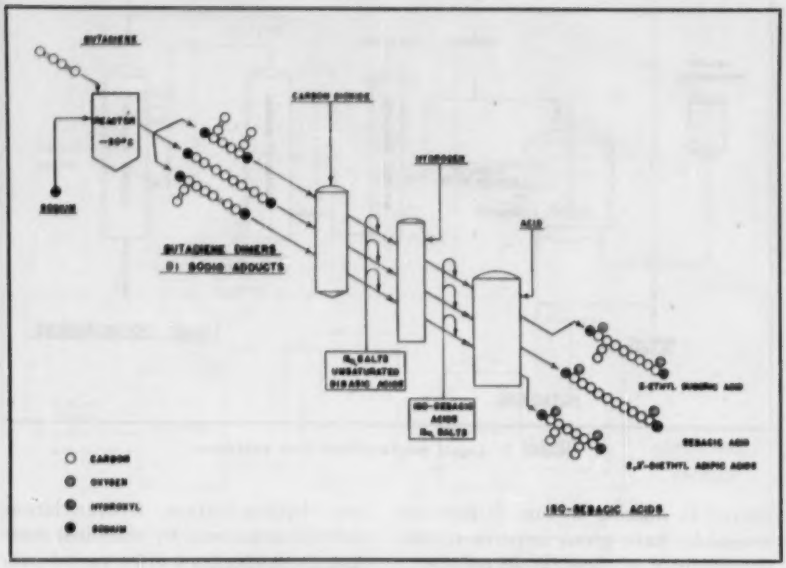


FIGURE 4—Isosebacic acids from butadiene.

drocarbon diluent such as n-heptane, which is necessary for control of the reaction, and is fed to the stirred reactor continuously. The metallic sodium dispersion, used as a catalyst, is also fed continuously. This mixture comprises about 30 weight percent butadiene. Temperature of the reaction is maintained at 85 to 95 C with a reaction time of about two hours. Under these conditions a high conversion of the butadiene is effected and there is recovered a solution containing almost 30 weight percent of the liquid polymer. The reactor effluent is quenched and passed to an off-gas separator where residual butadiene is removed. It is subsequently treated to remove the catalyst; for example, by contacting with water and carbon dioxide or other acidic materials. The diluent is separated and recycled, and liquid polybutadiene is recovered as the kettle product from the column.

Reaction temperature, diluent ratio, reaction time and catalyst concentration are used as the primary controls of the properties of the product. The product purification steps can be varied to yield a polymer of the desired viscosity, flash point and color.

**Isosebacic Acids**—Another process based on the sodio-derivative of butadiene which has recently been singled out for commercialization is the synthesis of isosebacic acids. The sodium-butadiene adduct is chemically very active and has long been known to react readily with acidic reagents, such as carbon dioxide. The difficulty has been in controlling the reaction, and only polymeric products, essentially derivatives of the liquid polybutadienes, have resulted. Recently, researches reported from the laboratories of National Distillers,[15] have shown that by careful control of several important variables in the process, the sodium addition-polymerization can be controlled to stop at the eight-carbon dimers, and subsequent carbonation then yields only dibasic acid derivatives of a single molecular weight, the ten-carbon sebacic acid isomers. Under construction and scheduled for completion in early 1957 by U. S. Industrial Alcohol, a National Distillers subsidiary, is a plant to produce 10 million pounds annually of this acid mixture.[16] The product is expected to go into vinyl resin plasticizers, alkyd resins, polyamide and polyurethane resins, and other applications.[17]

In the process, the initial dimerization of butadiene is carried out in the presence of very finely divided sodium. The alkali metal is prepared in a dispersion in which the average particle size is less than 50 microns. In this respect it resembles the liquid polybutadiene process, but in the isosebacic acid process, a further requirement is the use of very low reaction temperatures, in the range of —20 to —50 C. The sodium is suspended and reacted with the butadiene, which is led into the reactor, in a solvent in which a major fraction is an ether, diluted only with a small proportion of a hydrocarbon such as iso-octane. Here again the process varies somewhat from the liquid polybutadiene process, which may employ a minor quantity of an ether to modify the properties of the polymer. In the isosebacic acid process, such compounds as dimethyl ether, dioxan, and the polyethylene glycol ethers, have been found satisfactory. A final factor of importance in the isosebacic acid process is the presence in the solvent of a few percent of a polycyclic aromatic hydrocarbon, such as naphthalene, p-terphenyl, etc. The exact role of the activator has not been revealed; but it results in an increase in the selectivity of the dimerization and in the reaction rate, possibly by facilitating transfer of butadiene through the film of reaction product which forms on the sodium particle.

Three of the four possible combinations of the two doubly unsaturated four-carbon molecules take place readily, as shown in the chart, Figure 4. The fourth occurs only in traces; the total yield of the three dimers is reported to be 80-90 percent of the total butadiene reacting. Carbonation of the disodio butadiene dimers is carried out separately from the sodium reaction. This is essential to the process, since it has been found carbon dioxide hinders the selectivity and completeness of the sodium reaction. Attempts to separate the individual isomers are complicated by the presence of cis-trans isomers, racemic and meso forms, and the ease of isomerization of the double bond.

Hydrogenation of the sodium salts of the unsaturated acids is the next step, and the acids are then liberated by acidification and purified. No details have been released on these final steps in the process. The hydrogenation should be readily accomplished, and the remaining steps are straightforward.

The product comprises a mixture of the sebacic acid isomers. The

straight chain acid is expected to comprise 6 to 10 percent of the mixture, with 12 to 18 percent as the 2,2′-diethyl adipic acid isomer, and the remaining 72 to 80 percent as 2-ethyl suberic acid.

**Diels-Alder Reactions**—One of the most typical reactions of conjugated diolefins, is the condensation which occurs with compounds containing an activated olefinic linkage, commonly known as the Diels-Alder reaction. Extensive study has been given this reaction in laboratories throughout the world for a number of years; and literally hundreds of examples of it are known, a majority using butadiene as the diolefin. Yet only a few of these have attracted commercial interest so far.

Butadiene and furfural can be reacted in the ratio of two mols of butadiene to one mol of furfural to yield one mol of 2,3,4,5-bis-($\Delta^2$-butenylene)-tetrahydrofurfural.[18,19] This condensation product, usually referred to as butadiene-furfural cotrimer, has been found to have outstanding properties as an insect repellent.[20,21] For this purpose, Phillips Petroleum Company has manufactured this product in a semicommercial plant. The product is a clear liquid of yellow color and a very faint, pleasant odor. Typical properties of this product are given in Table 2.

**TABLE 2**
**Typical Properties of Butadiene—Furfural Cotrimer**

| | |
|---|---|
| Purity, mol percent (melting point) | 93.9 |
| Specific Gravity, $d\ \frac{20}{4}$ | 1.12 |
| Refractive Index, $n\ \frac{20}{D}$ | 1.525 |
| Color, Gardner | 4 |
| Viscosity, SUS at 100 F | 51.5 |
| Flash Point, COC, F | 300 |
| Furfural Content, percent | 0.1 |
| Boiling Range, F at 5 mm of Hg | 275–285 |

A flow diagram for a typical manufacturing operation for this product is given in Figure 5.[19] Furfural and butadiene are mixed, using a considerable molal excess of furfural which may vary from about 2 to 1 up to 10 or 20 to 1. The mixture is fed to a stirred autoclave continuously, at a rate calculated to give the desired several hours residence time. Heat is supplied to maintain the reaction, since the exothermic heat of reaction is not enough to balance the usual heat losses. The temperature will normally be below 450 F since at this level furfural polymerization begins to accelerate rapidly. A portion of the butadiene dimerizes to vinylcyclohexene.

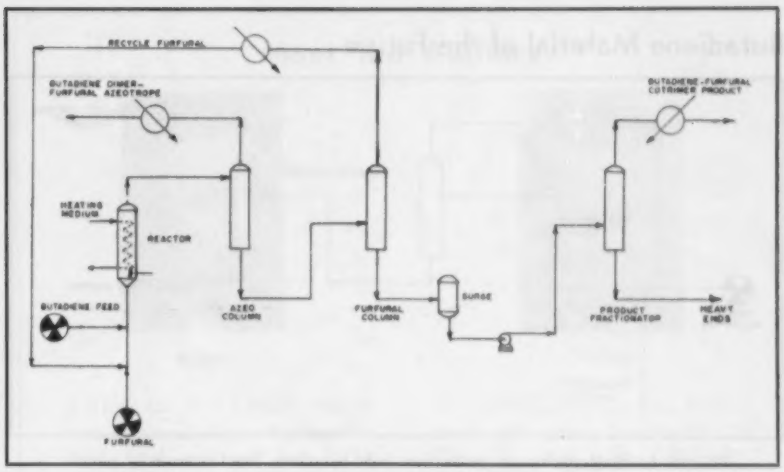


**FIGURE 5—Flow diagram for the production of butadiene-furfural cotrimer.**

Butadiene is generally present in small amounts in the reactor effluent from which it is stripped. Purification by fractionation involves distillation of the dimer (vinylcyclohexene), followed by the excess of furfural used, which is recycled to the reactor. The cotrimer is taken overhead in a final column to separate it from higher boiling materials. To avoid polymerization of the product, vacuum fractionation may advantageously be employed.

Among the dozens of Diels-Alder type condensations which are being reported steadily from the nation's research laboratories, products from at least two others of them have been or are in limited commercial production. Tetrahydrobenzaldehyde, resulting from the condensation of butadiene with acrolein, has been produced commercially by Carbide and Carbon Chemicals Corporation. It finds use as an antienzymatic ingredient in toothpastes. No details of the process or the extent of the operation have been made public. There should be no difficulty in carrying out the reaction under relatively mild conditions and in achieving reasonable yields.

A similar product, resulting from the familiar maleic anhydride reaction, is tetrahydrophthalic anhydride, which National Aniline Division has recently offered as a development chemical in pilot plant quantities. This familiar reaction, the basis of the gravimetric analysis of butadiene, is readily carried out by bubbling gaseous butadiene through molten maleic anhydride, generally below 100 C to minimize dimerization and other side reactions. The rate of reaction and the temperature may readily be controlled by the rate of addition of the butadiene.

The reaction may be further moderated by using the maleic anhydride in solution in a solvent such as benzene. The reaction can be taken easily to substantially complete consumption of the maleic anhydride, thus minimizing purification problems and insuring yields of 95 percent and better. Tetrahydrophthalic anhydride would be expected to find similar uses to pthalic anhydride, in alkyds, ester plasticizers, dyes, etc., where the presence of the olefinic bond in the ring might lead to interesting modifications in the products. No plans for full scale manufacture have been announced and it must be presumed no attractive use has yet developed.

Butadiene dimer, 4-vinyl-1-cyclohexene, results also from a Diels-Alder type condensation between two molecules of butadiene. Appreciable quantities form at temperatures as low as 100 F, under conditions of long storage; the quantities increase rapidly with temperature so that dimerization is a factor of measurable importance in various distillations and purification processes, and in reactions in-

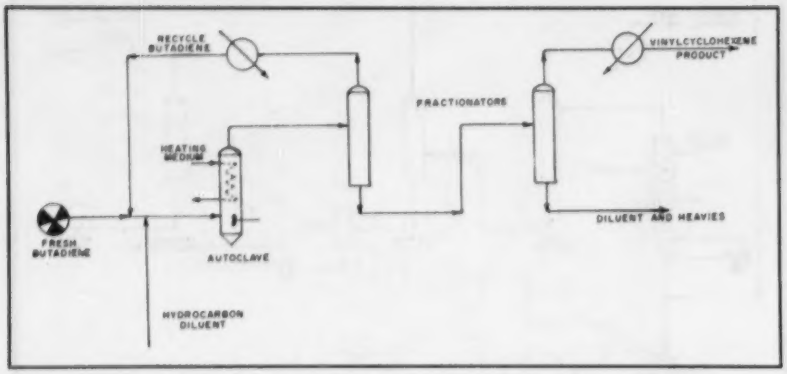


FIGURE 6—Vinylcyclohexene production from butadiene (semi-commercial plant).

volving butadiene at elevated temperatures.

The dimer, recovered from operations of this type, has been offered for sale at intervals. Manufacture has involved merely stripping off the butadiene and a simple distillation of the product, boiling at 265 F. Manufacture of vinylcyclohexene as a main product has not been announced, but processes are available whenever the market justifies such production. Low temperature (200-300 F) liquid phase processes under several hundred pounds pressure result in high ultimate yields of a pure product, but require residence times on the order of hours to secure appreciable yields.

The required residence time may be reduced to a few minutes, or even seconds by use of vapor phase reactions at 600-1000 F, but with a reduction in ultimate yield and the associated formation of complex by-products which must be separated by careful fractionation. Another dimer, 1,5-cyclooctadiene may be produced in appreciable yield by proper control of conditions, if desired.[22] Figure 6 illustrates one process for manufacture of dimers. It has been reported that considerable interest in vinylcyclohexene has been displayed at relatively low price levels. An active interest in the dimer for conversion to mono- and dioxides (epoxides) seems to be developing.[23]

**Oxidations**—Several oxygenated products derived from butadiene have been carried to the point of offering pilot plant quantities for purposes of market development. Butadiene monoxide (3,4-epoxy-1-butene) was the first of these, produced several years ago in limited quantity by Columbia Southern Chemical Company. The chemical, analogous to ethylene oxide, was manufactured similarly by the standard hypochlorous acid route.[24] Direct air oxidation of butadiene over silver catalysts is attended by serious control problems not experienced in applying this process to ethylene; evidently they have not been satisfactorily solved and the hypochlorous acid route remains the only practical one at present. The chemical has not been available on the market for several years, having been withdrawn when no major uses developed. However, the extremely reactive nature of the compound with the active olefinic bond, the epoxy group and the potential aldehyde reactions inherent in the structure maintain a high interest in it as a chemical building block, and it may once again enter the list of commercially available butadiene derivatives.

When butadiene is reacted with hydrogen peroxide in the presence of per-acids a mixture of glycols is obtained. In researches from the laboratories of Phillips Petroleum Company, details of a process for preparation primarily of the tetrahydroxy derivative erythritol, are given.[25] According to these reports, butadiene is treated with aqueous hydrogen peroxide, using methyl formate as catalyst. This ester has proved to be as effective a catalyst as formic acid and has the advantage that it is readily recycled. Using 10 percent hydrogen peroxide in a mol ratio of 2 to 1 on the butadiene, and with two moles of methyl formate catalyst per mol of 80 to 122 F, yields of erythritol and the intermediate dihydroxybutene may reach 80 percent, with less than five percent of the butadiene lost as polymer.

After stripping off the catalyst, the diol is separated from the erythritol by solvent extraction.[26] Meso-erythritol is readily recovered by crystallization; the d,l-erythritol formed in equal amount is more difficult to

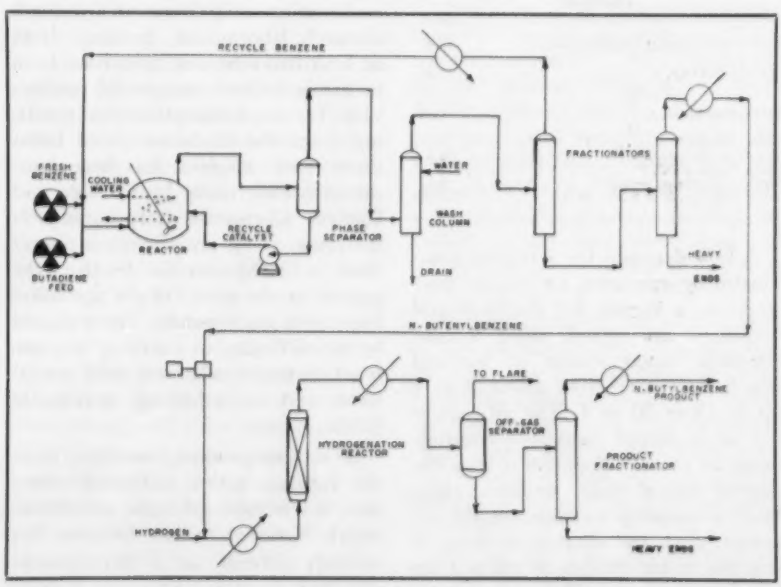


FIGURE 7—Normal butylbenzene from butadiene and benzene.

crystallize, but by a special two stage process both can be recovered in pure form.[27] A large market exists for polyhydric alcohols in solvents, plasticizers, glyptal and alkyd type resins, etc.; erythritol might compete with pentaerythritol, glycerine, etc., in this area. Explosives based on the tetranitrate may find commercial application, however. No plans for carrying erythritol further into commercial production have been announced.

Representative of processes in which substitution of butadiene for more conventional feed stocks provides better yields are the oxidation of $C_4$ hydrocarbons to maleic acid and the synthesis of thiophene. Oxidation of butylenes to maleic anhydride over vanadium pentoxide catalyst has been commercially practiced. Butadiene is a useful feed stock, giving somewhat increased yields, but current cost of the diolefin would seem to rule out consideration of it. Researches at Socony-Vacuum laboratories resulted in development of a process for making thiophene from butane and sulfur.[28] Unsaturated hydrocarbons gave increased yields, reaching a maximum with butadiene.[29] At present, economics are unfavorable to the use of butadiene in the processes.

## Meet the Authors

Hillyer

JOHN C. HILLYER graduated from Carleton College in 1929, and received his Ph.D. from Yale University in 1932. For the next five years he was a chemistry instructor at Carleton College, then in 1937 he joined the research division of Phillips Petroleum Company. At the present time Dr. Hillyer is section manager of the research division of Phillips and is in charge of research on chemical uses of butadiene, and other organic and inorganic chemical developments. Hillyer is the author of several technical papers, and holds more than 60 U. S. and foreign patents.

Stallings

P. S. STALLINGS, JR., graduated from the University of Texas in 1940 with a B.S. degree in chemical engineering, and is now pilot plant manager of the Philtex experimental station of Phillips Petroleum Company, at Phillips, Texas. In this position, he is in charge of both the pilot scale development of products and processes applicable to the petroleum industry, and the manufacture of Phillips' line of high-purity hydrocarbons. Prior to joining Phillips, Stallings spent nearly five years developing new items of ammunition for the War Department.

**Alkylation**—The synthesis of n-butylbenzene has been accomplished in laboratory and pilot plant operations by the alkylation of benzene with 1,3-butadiene to form n-butenylbenzene, followed by the hydrogenation of the n-butenylbenzene.[30]

A flow diagram for the pilot plant production of n-butylbenzene is shown as Figure 7. First, benzene and butadiene are condensed in a semicontinuous reaction by charging the reactor, containing a $BF_3$ solution as catalyst, with the benezene-butadiene mixture. The benzene-butadiene mol ratio is maintained at about 4 or 5. The reaction is carried out at approximately 60 F and atmospheric pressure with a residence time of about one hour. The reactor effluent is allowed to separate into two phases. The catalyst phase is recycled, and the hydrocarbon phase is fractionated to recover the unreacted benzene which is recycled.

The n-butenylbenzene is then hydrogenated over nickel catalyst at a temperature of about 550 F and a pressure of about 150 psig. The hydrogenated product is then given a final fractionation to recover the n-butylbenzene. The condensation of benzene and butadiene must be carried out in stainless steel or glass equipment because of the corrosiveness of $BF_3$; however, all of the other equipment used in the production of n-butylbenzene can be constructed of carbon steel.


### ACKNOWLEDGMENT

The authors wish to express their appreciation to Phillips Petroleum Company for their permission to publish this article. The authors also wish to thank Dr. C. M. Oktay for his assistance.


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'56 Petrochemicals

# Look Again at the Synthetic

**Here's a quick review that points out the importance of petrochemicals in the synthetic rubber industry.**

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The Goodyear Tire and Rubber Company, Akron, Ohio

SYNTHETIC RUBBER has come of age. The polymer chemist has improved its quality to the point that it is *preferred* to the natural product for many applications. He has mastered his science so well in the last two decades that he can produce many polymers tailored to the requirements of a specific end use. He can synthesize even natural rubber itself. This recent development poses more of a threat to producers of natural rubber than to producers of current synthetic rubbers.

The rubber industry was almost totally dependent upon natural rubber prior to World War II. Fortunately, the rubber manufacturers, oil companies, and others had started research and development on synthetic rubber in the previous decade. When the enemy cut us off from rubber supplies, enough technical know-how had been built up to serve as the base for a rapidly expanding synthetic rubber industry. A truly cooperative program of the government, rubber, oil, and chemical companies compressed into a few years the development of a new industry which otherwise would have required 20 years for normal growth. The government-owned plants produced tremendous quantities of butadiene-styrene rubber through the war and post-war years. Finally, in the Spring of 1955, the plants were purchased by rubber, oil, and chemical companies.

This is a period of keen competition for the customer's business. Many of the producers are large consumers of their own rubber. However, all are anxious to sell their products to others, especially the small consumer. The percentage sold to the small consumer has exceeded that specified as one condition for purchase of the government-owned plants. Capacity of the plants is being greatly increased in anticipation of the larger market predicted for the future.

Butadiene-styrene rubbers are the work horse of the industry, accounting for about 80 percent of all synthetic rubbers consumed in the U. S. A. The other important types are neoprene, butyl, and the nitrile-type copolymers. Recent developments indicate the future importance of still others, such as the polyurethanes, synthesized natural rubber (*cis*-polyisoprene), and *cis*-polybutadiene. Nearly all of these are based on raw materials (butadiene, styrene, chlorobutadiene, isobutylene, isoprene, acrylonitrile, etc.) which are petrochmecials.

**Butadiene-Styrene Rubbers**—Butadiene-styrene rubbers are usually produced so as to contain about 77 percent butadiene and 23 percent styrene in the copolymer. Figure 1 illustrates in a general way the production of butadiene-styrene rubber. The original polymer (GR-S) produced in the government plants was made at

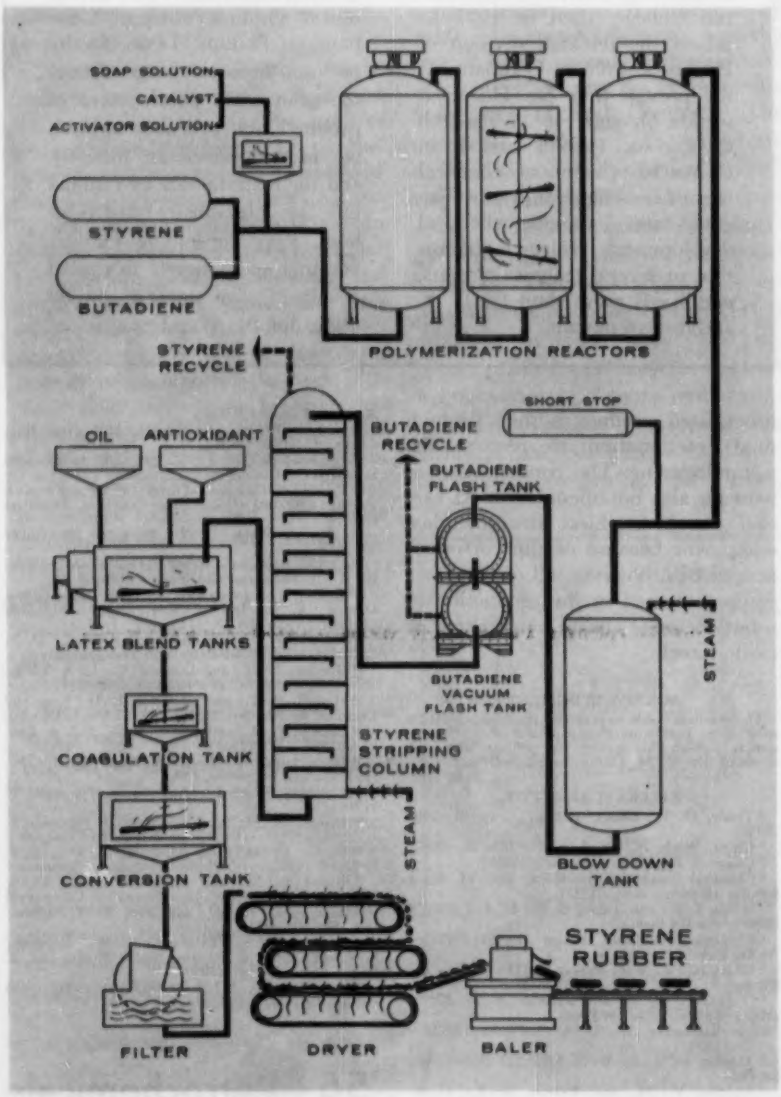


FIGURE 1—Simplified flow diagram showing the manufacture of styrenebutadiene rubber.

# Rubber Industry

a relatively high temperature (122 F) and to a 72 percent conversion of monomers to polymer. The monomers were emulsified in water containing soap and a catalyst (potassium persulfate). A small amount of modifier (dodecyl mercaptan) was added to the monomers to regulate the molecular weight so the polymer could be used in conventional rubber processing equipment.

The polymer chemist effected a substantial improvement in quality when he learned that a lower polymerization temperature (41 F) and lower conversion (60 percent) produced a better polymer, cold rubber, especially for tire treads. Special activators were developed to allow polymerization to occur at the lower temperature. Tread life was increased 22 percent by cold rubber, which went into production in 1948. Later, petroleum oils emulsified and added to the latex (containing polymer of high molecular weight) prior to coagulation resulted in oil-polymer masterbatches of lower cost and higher quality than regular cold rubber. Tire treads made of oil-masterbatches (37.5 parts oil per 100 parts rubber) have outworn regular cold rubber treads by a 15 percent margin.

Dozens of different butadiene-styrene rubbers are now available from a number of producers. Special varieties are processed to give low water absorption, low ash content, and excellent electrical properties. The general-purpose varieties nearly all fall into a relatively few categories:

Type

- Hot, Non-Pigmented
- Cold, Non-Pigmented
- Cold, Oil Masterbatch (25 Parts Oil/100 Rubber)
- Cold, Oil Masterbatch (37.5 Parts Oil/100 Rubber)
- Hot, Black Masterbatch (50 Parts Black/100 Rubber)
- Cold, Black Masterbatch (50 Parts Black/100 Rubber)
- Cold, Oil-Black Masterbatch (50 Parts Black, 25 Parts Oil/100 Rubber)

Some of the variations found in this group are: bound styrene content, Mooney viscosity, emulsifier (fatty acid), rosin (acid or mixture), antioxidant (staining or non-staining), and coagulant (salt-acid, alum, glue-acid, etc.)

The butadiene-styrene rubbers are produced and sold by a large number of rubber and petroleum companies as shown in Table 1:

It is estimated that expansions now in progress, plus others in the planning stage, will raise the annual *net* polymer capacity in the U. S. by January, 1958, to a total of 1,217,200 long tons of butadiene-styrene rubbers.[1] In addition to the plants listed, General Tire & Rubber Company is planning to construct at Odessa, Texas, an entirely new facility to produce 40,000 long tons per year of butadiene-styrene rubbers. If one adds the oil content of the oil masterbatches, the *gross* polymer capacity by January, 1958, will reach a grand total of more than 1.4 million tons. In addition, Polymer Corporation, Ltd., at Sarnia, Ontario, is expected to have, at the end of 1956, an annual production capacity of 110,000 long tons of styrene, butyl, and nitrile rubbers.

Butadiene-styrene rubbers are general-purpose polymers of chief value in passenger tire treads. They are superior to natural rubber because of increased resistance to wear and cracking. They are also suitable for treads on small truck tires, and are being increasingly investigated for sidewall and carcass stock applications as well. They are also well suited for use in many industrial rubber products. One great virtue is their ability to be blended with natural rubber in any desired ratio to give satisfactory products.

**Neoprene**—The raw materials for neoprene are acetylene and hydrogen chloride. The acetylene is dimerized to vinyl acetylene, to which is added hydrogen chloride. The adduct then rearranges to the monomer, 2-chloro-butadiene-1,3 ($CH_2=C-CH=CH_2$, with Cl on the second carbon).

Most of the neoprenes are polymers of this monomer, but in a few cases small amounts of others are used to make copolymers.

Neoprene is produced exclusively by du Pont in plants at Louisville, Ky., and at Montague, Mich., (now in final stages of construction). Capacity of the Louisville plant (purchased from the government) is 100,000 long tons per year and the Montague plant will add another 25,000 long tons per year.

Neoprene has a number of excellent properties such as resistance to swelling in gasoline and other solvents, excellent weathering and age-resistance, high gum tensile strength, etc. In many of its applications, such as paper and fabric impregnation and coating, it is used in the form of latex. For applications where oil resistance is a factor, neoprene and nitrile rubbers are active competitors. Nitrile rubbers are often preferred where high oil resistance is required.

Although this special rubber has been marketed since 1931, new uses continue to be found and rapid growth in consumption should occur.

**TABLE 1—Synthetic Rubber Producers**

| | | Annual Net Polymer Capacity Rated Capacity —April, 1955 (1000 Long Tons) |
|---|---|---|
| Copolymer Rubber & Chemical Corp. | Baton Rouge, La. | 49 |
| Firestone Tire & Rubber Co. | Akron, Ohio | 30 |
| | Lake Charles, La. | 100 |
| United Rubber & Chemical Co. (Sales Agent, United Carbon Co.) | Baytown, Tex. | 44 |
| Goodrich-Gulf Chemicals, Inc. | Port Neches, Tex. | 90 |
| | Institute, W. Va. | 122 |
| Goodyear Tire & Rubber Co. | Akron, Ohio | 15 |
| | Houston, Tex. | 100 |
| American Synthetic Rubber Corp. | Louisville, Ky. | 44 |
| Shell Chemical Corp. | Los Angeles, Calif. | 80 |
| Phillips Petroleum Co. | Borger, Tex. | 63 |
| U. S. Rubber Co. (Naugatuck Chemical) | Naugatuck, Conn. | 22 |
| Texas-U.S. Chemical Co. (Sales Agent, Naugatuck Chemical) | Port Neches, Tex. | 88 |
| TOTAL | | 856 |

U. S. consumption plus exports in 1955 amounted to 91,000 long tons, so that output of the new plant at Montague will be required in the near future.

**Butyl Rubber**—The butyl polymers are produced by the copolymerization of isobutylene and a small amount (1.5-4.5 percent) of isoprene. They were developed by Standard Oil of New Jersey and produced as GR-I in U. S. government-owned plants during World War II. In March, 1955, the plants were sold to private interests. The Baton Rouge, La., plant (47,000 long tons per year capacity) was sold to its operator, Esso Standard Oil Company, and the Baytown (Texas) plant (43,000 long tons per year capacity) was sold to its operator, Humble Oil & Refining Company (a New Jersey Standard affiliate). Under terms of the purchase agreement, Esso is obligated, until April, 1958, to sell the Baton Rouge facility to a bona fide purchaser unless butyl production facilities of at least 43,000 long tons per year capacity have been substantially completed in the country prior to receipt of such an offer.

Licenses to the butyl rubber patents have been granted to B. F. Goodrich Company (1950), Goodrich-Gulf Chemicals, Inc. (1953), and Petroleum Chemicals, Inc. (1954). One recent news item of interest is that Thiokol Corporation plans to market butyl rubber and is establishing a sales, research, and development laboratory at Trenton, N. J., for this purpose. Petroleum Chemicals, Inc., is helping with this program, and, if prospects are favorable, will consider building a $25 million butyl plant at Lake Charles, La. In the foreign field, a combination of oil, rubber, and chemical companies has taken a license and is planning to install butyl rubber facilities in France in the near future.

The properties of butyl rubber reflect its unique molecular structure. Chemical and weathering resistance are due to the very low unsaturation of the polymer. Low air diffusion is probably a result of the close-packed structure formed by long chains of isobutylene units. Low unsaturation requires the use of a specially activated curing system, and prohibits blending of butyl with highly unsaturated rubbers such as natural rubber and butadiene-styrene copolymers. Small amounts of these in butyl rubber stocks would "rob" the butyl rubber of sulfur and other curative agents, and result in useless stocks. On the other hand, natural rubber or butadiene-styrene rubbers can tolerate appreciable amounts of butyl rubber as diluent without serious effect on vulcanization. A brominated butyl rubber has been suggested to obtain good adhesion between butyl stocks and natural or butadiene-styrene rubber stocks.

Butyl rubber lost an appreciable portion of its market with the rapid switch in the last two years from tube-type to tubeless passenger and truck tires. Some manufacturers of tubeless tires, however, still employ a sizable amount of butyl rubber as an air-retaining inner liner for tubeless tires. The use of butyl rubber for other rubber products used in automobile parts, however, is helping to offset this loss. One 1956 make of car is stated to have butyl rubber parts (shock absorbers, window seals, radiator hose, foot pedal covers, etc.) which require twice as much rubber as formerly employed in five inner tubes.

A still more recent development is the all butyl passenger car tire, developed by Esso Research & Engineering Company, and soon to be test-marketed by Esso Standard Oil Company in a program calling for production of 100 tires a day. (The tires are being produced by Armstrong Rubber Company at its West Haven, Conn., plant.) Atlas Supply Company, which supplies tires, battery and accessories to Esso and others, is considering marketing a butyl tire, but has not set a definite date for this program.

Many claims for advantages of butyl tires over regular tires have been made, but some of them will require additional testing and experience for complete substantiation. These claims include less cracking due to weathering (including ozone and sunlight effects), quicker stopping on wet or dry pavements, greater riding comfort, lower noise level, and better air retention. Nothing has been said concerning performance in very cold weather or on ice or snow.

Esso Research has spent $14 million to develop the butyl tire. One of the major accomplishments was the development of a butyl "latex" (a stabilized suspension of butyl rubber in water) which permitted the satisfactory bonding of carcass stocks to tire fabric.

A number of rubber companies have been experimenting with butyl tires for several years and at least two automobile manufacturers are stated to have requested trial lots of butyl tires from suppliers.

The long term outlook for butyl rubber is a favorable one, even though the loss of much of the inner tube market was a serious blow. The unique properties of butyl make it very valuable for many industrial products, fabric coatings, wire and cable insulation, etc. Ample production capacity exists and since it is a low priced synthetic rubber there is much incentive for broadening its markets. Increased exports and new applications should tend to raise total requirements in the next few years.

**Nitrile Rubbers**—Nitrile rubbers are copolymers of butadiene and acrylonitrile in varying ratios. The combined acrylonitrile content in commercial rubbers ranges from approximately 18 to 45 percent. They were developed in this country by oil and rubber companies in 1935-1940, but were pioneered in Germany as Buna N.

Nitrile rubbers are produced and sold by Firestone Tire & Rubber Company, B. F. Goodrich Chemical, Goodyear Tire & Rubber Company, and U. S. Rubber Company. Plant capacity increased from 25,000 long tons at the end of 1954 to 40,800 long tons at the end of 1955. Additional expansions are planned.

Nitrile rubbers possess good resistance to oils, solvents, and chemicals. They also possess high tensile strength, good aging and heat resistance, good electrical properties, and excellent processing characteristics. As acrylonitrile content increases, oil resistance increases but low temperature flexibility decreases. By selection of the proper polymer and the addition of a suitable plasticizer, the rubber compounder can achieve satisfactory formulations for many applications.

Some of the end products which use nitrile rubbers (or in some cases neoprene) are O-rings, hose, gaskets, fuel cells, tank linings, printing supplies, flooring, shoe soles, fabric coatings, pump impellers, oil well swabs,

pipe thread protectors, wire covering, rubber gloves, food films, cements and adhesives.

Production of nitrile rubbers has expanded rapidly in recent years. Usage of nitrile rubber latex has greatly increased for coating and impregnation of paper, fabric, carpet backings, etc.

**Synthetic "Natural" Rubber**—The synthesis of "natural" rubber has excited the greatest interest in the past two years, and represents a major milestone in the history of the rubber industry. For many years, rubber chemists have known that the structure of natural rubber is *cis*-1,4-polyisoprene, in which practically all of the isoprene units are arranged in a very regular fashion which permit the molecules to crystallize on extension. However, this structure could not be duplicated by polymerization of isoprene with the types of processes publicly known up to two years ago.

In December, 1954, B. F. Goodrich Company announced the successful synthesis of "natural" rubber and later (November, 1955) disclosed that it was based upon information on the preparation of polyolefins purchased from Dr. Karl Ziegler, Director of the Institute for Coal Research, Germany. The synthesis was announced as the accomplishment of scientists of Goodrich-Gulf Chemicals, Inc., owned by B. F. Goodrich and Gulf Oil Corporation. Physical examination of the polymer, through infrared, X-ray, and other methods of evaluation, and its use in applications, such as heavy duty truck tires, confirm the fact that its properties are practically identical with those of the natural polymer. A pilot plant is being erected at Avon Lake, Ohio to study the reaction more intensively and to prepare for ultimate large-scale production. Goodrich recently announced that military truck tires of its synthetic "natural" have been found superior to standard military truck tires in Army Ordnance Tests. The tires passed all military requirements and were stated to be superior to the standard military tires in some respects (tread wear, tread life, tread cutting resistance, and tread splice).

In August, 1955, Firestone Tire & Rubber Company announced the successful synthesis of *cis*-1,4-polyisoprene. In November, 1955, it was disclosed that the new rubber could be made in a simple formula consisting of 100 parts isoprene and 0.1 part lithium at a reaction temperature of 30 to 40 C. It is strikingly similar to Hevea rubber, as indicated by infrared absorption, X-ray diffraction, ozonolysis, unsaturation, carbon-hydrogen ratio, molecular weight distribution, inherent viscosity, and other factors. Firestone recently announced the successful testing of military truck tires made of its synthetic "natural" in place of natural rubber. The tests were conducted by U. S. Army Ordnance on heavy duty tires, 14.00 x 20, on loaded military vehicles operating over rough terrain and in extreme summer heat at Camp Bullis, near San Antonio, Texas. The performance was stated to meet all military requirements.

In October, 1955, Goodyear Tire & Rubber Company disclosed that its scientists had successfully employed a Ziegler-type catalyst to prepare a synthetic polyisoprene possessing a molecular structure very similar to that of natural rubber. The catalyst was made by combining aluminum triethyl with a co-catalyst. The infrared absorption pattern of the new polymer was markedly different from that of the emulsion polymer, and substantially identical with that of natural rubber.

In April, 1956, Phillips Petroleum stated that its scientists had successfully prepared a *cis*-1,4,polybutadiene rubber which generates less heat than styrene synthetic rubber, and approaches natural rubber in this respect. Its resilience is 10-15 percent better than for styrene rubber, and it performs better at low temperatures. Another form (*trans*-isomer) is a high softening point resin with many potential applications. With isoprene, the counterparts of Hevea rubber and gutta percha have also been prepared. The catalysts are of the "stereospecific" or "directive" type and probably related to those used for Phillips' high density polyethylene.

Most recently, R. S. Aries Associates, Inc., have described the successful synthesis of an all *cis*-1,4-polybutadiene, using a catalyst prepared from butyl lithium and titanium trichloride. This catalyst has also been used to prepare rubberlike copolymers resembling butyl rubber from a mixture of ethylene and propylene with a small amount of isoprene to produce unsaturation in the polymer.

It is clear that all of these syntheses have opened up a vast new field for exploitation, and, in all cases, petroleum raw materials are involved. Further developments in this field can be anticipated in the near future.

The synthesis of polymers practically identical with natural rubber is of great scientific importance and has long term significance not only to the rubber industry but to the country from the standpoint of national defense. For the first time in history, we can foresee complete independence from the Far East sources of a vital raw material. However, in the absence of a war emergency which tremendously accelerated the GR-S development, progress will probably be slower on polyisoprene. The rubber industry is expecting the petroleum

**Meet the Author**

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Dr. D'Ianni started as a research chemist in the organic chemistry section and was promoted to supervisor of synthetic rubber organic research in 1943. For a short while he was on leave to the Office of Rubber Research, RFC, Washington, D. C., and upon returning to Goodyear in 1947, he was made section head of rubber chemical derivatives. Later that year he was made section head in charge of vinyl polymers and synthetic rubber. He became section head in charge of diene and vinyl polymer research in 1948 and took over his present duties in 1952.

industry to make isoprene available in large quantities and at a low price so that synthetic polyisoprene can compete with natural rubber. Many industry observers believe that isoprene of high purity must be available in the price range of 15-20 cents per pound to accelerate this development. The cost of the conversion to polymer will undoubtedly be somewhat higher than for the butadiene-styrene rubbers made by emulsion polymerization processes. Natural rubber producers will do their utmost to maintain position, since it is understood that on the most efficient plantations rubber can be produced and sold profitably for as low as 15 cents per pound.

**Market Factors**—In 1955, synthetic rubbers accounted for 58.5 percent of all the rubbers consumed in the U. S. as shown in Table 2.

**TABLE 2**
**1955 U. S. Rubber Consumption**

| TYPE | Consumption (Long Tons) | Percent |
|---|---|---|
| Natural Rubber | 634,800 | 41.5 |
| Butadiene-Styrene Rubbers | 741,997 | 48.5 |
| Neoprene | 72,876 | 4.8 |
| Butyl | 53,991 | 3.5 |
| Nitrile Rubbers | 26,035 | 1.7 |
| Total | 1,529,699 | 100.0% |

Synthetic rubbers are preferred to natural rubber in applications which consume about one-third of the rubber used, natural rubber is preferred in applications consuming one-third of the rubber used, and the remaining one-third is an area of active competition where economic factors are of paramount importance. In 1955, natural rubber sold in the price range of about 30 to 50 cents per pound, whereas butadiene-styrene rubber sold for about 24 cents per pound. The relative amounts used have fluctuated greatly in the last decade, depending to a large extent upon the relative cost and availability of each type as shown in Table 3.

The various synthetic rubbers are currently sold at prices such as shown in Table 4.

**TABLE 4**
**Typical Synthetic Rubber Prices**

| (Cents/Pound Delivered Basis) | |
|---|---|
| Butadiene-Styrene Types (Including oil masterbatches) | 18.85—24.1 |
| Neoprene | 40—56 |
| Butyl | 24.1 |
| Nitrile Rubbers | 48—64 |

It is interesting to look over the figures for the past decade of the U. S. consumption and exports of synthetic rubbers (Table 5). Consumption of butadiene-styrene rubbers has fluctuated widely, since amount consumed is considerably affected by the price of natural rubber. Neoprene and nitrile rubbers have shown good gains, especially in 1955, whereas U. S. consumption of butyl has declined steadily since 1953.

Exports of synthetic rubbers have risen markedly in 1955 and 1956. The high values reflect the high price of natural rubber and the industrial boom in Western Europe. Total exports in 1955 were 93,290 long tons and will exceed 150,000 long tons in 1956 if the rate for the first 6 months is maintained for the rest of the year. Exports should continue to increase for some time, at least until substantial production facilities for the production of synthetic rubbers have been established in foreign countries.

Tires and tire products still consume the bulk of the rubber in the U. S. (Table 6). Other products are gaining in importance and, in some cases, such as latex foam, are growing at a faster rate than transportation products. It is quite probable that in the long run non-transportation items will require increasingly larger percentages of the total rubber used. Up to the present time, transportation products have taken about two-thirds of the rubber consumed in the country each year.

**TABLE 6**
**U.S.A. Consumption of Natural and Synthetic Rubber in 1955**
**(Estimated Distribution by Product)**

| | Long Tons |
|---|---|
| Tires and Tire Products | 960,000 |
| Mechanical Goods | 150,000 |
| Latex Foam Products | 88,000 |
| Shoe Products | 60,000 |
| Athletic Goods, Toys, Stationers' Goods and Sponge Rubber | 60,000 |
| Insulated Wire and Cable | 43,000 |
| Footwear | 25,000 |
| Proofed Goods | 20,000 |
| Hard Rubber Products | 15,000 |
| Flooring | 15,000 |
| Cements | 15,000 |
| Drug Sundries | 5,000 |
| Miscellaneous | 74,000 |
| Total | 1,530,000 |

Source: "Rubber Map of the World," a brochure of Naugatuck Chemical, Division of United States Rubber Company.

**TABLE 3—Pattern of Synthetic Versus Natural Rubber Consumption U. S. 1946-1955**

| YEAR | PERCENT OF TOTAL CONSUMPTION | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1946 | 1947 | 1948 | 1949 | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 |
| Natural Rubber | 26.7 | 50.1 | 58.7 | 58.1 | 57.2 | 37.4 | 36.0 | 41.4 | 48.4 | 41.5 |
| Synthetic Rubber | 73.3 | 49.9 | 41.3 | 41.9 | 42.8 | 62.6 | 64.0 | 58.6 | 51.6 | 58.5 |

**TABLE 5—U. S. Consumption and Exports of Synthetic Rubbers**
**(Long Tons)**

| YEAR | BUTADIENE-STYRENE | | NEOPRENE | | BUTYL | | NITRILE | |
|---|---|---|---|---|---|---|---|---|
| | U. S. | Exports | U. S. | Exports | U. S. | Exports | U. S. | Exports |
| 1946 | 632,126 | 68,763 | 44,357 | 2,642 | 79,228 | 495 | 5,988 | 797 |
| 1947 | 448,589 | 7,951 | 37,703 | 2,617 | 68,838 | 62 | 4,536 | 755 |
| 1948 | 345,313 | 1,093 | 32,118 | 2,875 | 58,870 | 21 | 5,771 | 885 |
| 1949 | 321,137 | 1,401 | 31,753 | 3,330 | 52,664 | 178 | 8,827 | 1,574 |
| 1950 | 416,230 | 900 | 43,781 | 4,826 | 66,348 | 31 | 11,930 | 1,895 |
| 1951 | 626,444 | 483 | 48,887 | 6,825 | 70,500 | 216 | 13,066 | 1,725 |
| 1952 | 666,420 | 9,467 | 55,522 | 9,813 | 71,229 | 126 | 13,866 | 2,695 |
| 1953 | 624,181 | 7,692 | 65,900 | 11,494 | 77,826 | 237 | 16,929 | 3,245 |
| 1954 | 500,345 | 11,069 | 57,203 | 12,062 | 61,464 | 2,831 | 17,715 | 4,155 |
| 1955 | 741,997 | 60,704 | 72,876 | 18,098 | 53,991 | 9,895 | 26,035 | 4,593 |
| 1956 (1st 6 mos.) | 374,397 | 57,817 | 37,696 | 10,925 | 25,432 | 5,066 | 12,977 | 3,055 |

Source: Chemical and Rubber Division, B D S A, U. S. Department of Commerce.

**Summary**—Synthetic rubber has come of age and has greatly stabilized the operations of the rubber industry. It has substantially eliminated one of the largest variables in cost of the manufacture of rubber products. Our dependence on natural rubber has been greatly reduced, with the prospect that it may be completely eliminated if the synthesis of "natural" rubber can be placed on a sound economic basis.

The petroleum and chemical industries have made great contributions to the synthetic rubber program through the development and production of low cost raw materials, as well as of the polymers. The rubber industry will continue to be dependent upon these industries as the source of raw materials for present synthetic rubbers and the new types which are appearing on the horizon.

Continued close cooperation of these industries will be of great economic value to all concerned, and may be of critical importance to the free world should another international emergency arise.

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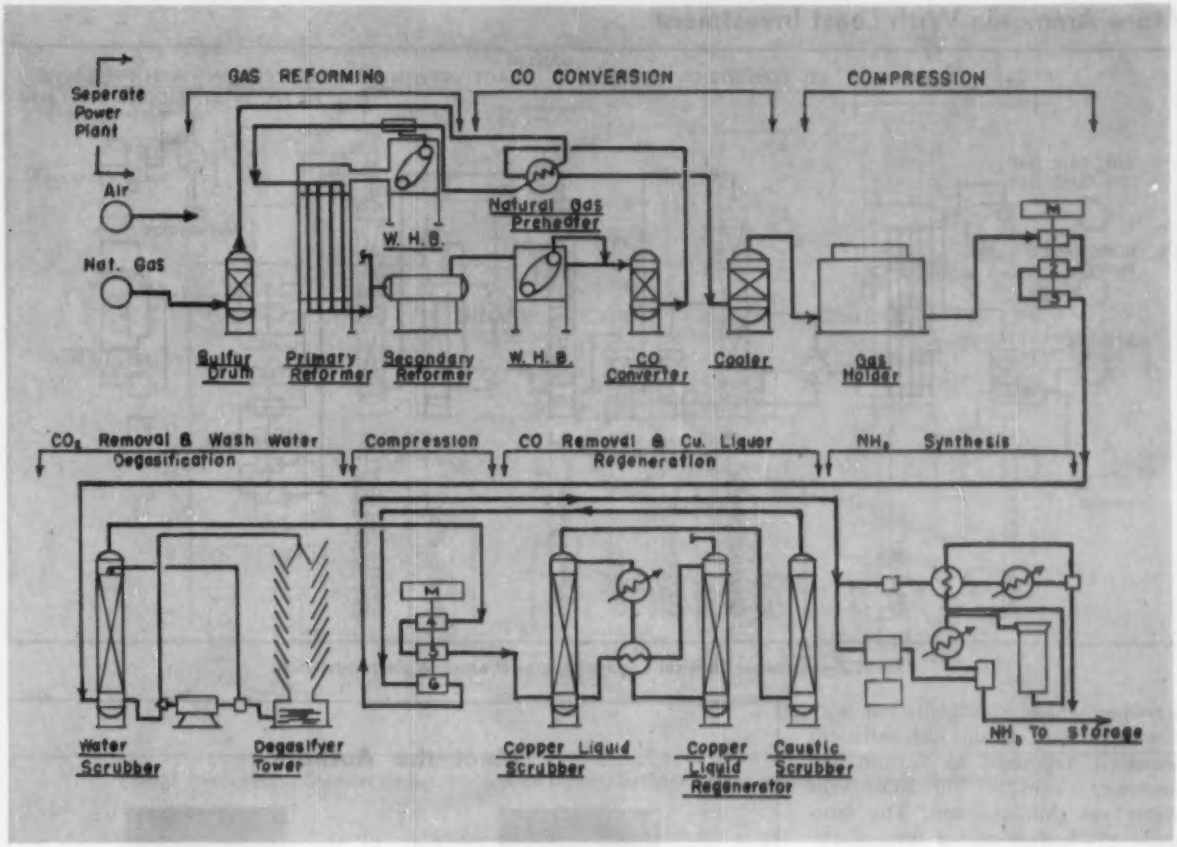



FIGURE 1—Conventional type ammonia plant.

# More Ammonia With Least Investment

Petrochemicals 56

**By low pressure methanation, you can increase ammonia production with fixed compressor capacity and still keep investment low.**

**W. B. Dunwoody and J. R. Phillips**
Mississippi Chemical Corporation
Yazoo City, Miss.

THE SUCCESSFUL production of anhydrous ammonia depends on producing a synthesis gas which is essentially free of carbon dioxide, sulfur and high concentrations of water vapor. These impurities poison the ammonia synthesis catalyst.

A flow diagram of a conventional ammonia plant is shown in Figure 1. Figure 2 is a flow diagram of the original system used by Mississippi Chemical Corporation. Figure 3 shows the addition of the second stage carbon monoxide conversion and low pressure methanation units to the original plant. Table 1 gives the gas analysis obtained while using these three different methods of synthesis gas purification.

**Low Pressure Methanation**—Impure synthesis gas (see Figure 3) containing 1.5-2 percent carbon monoxide enters from the first stage amine

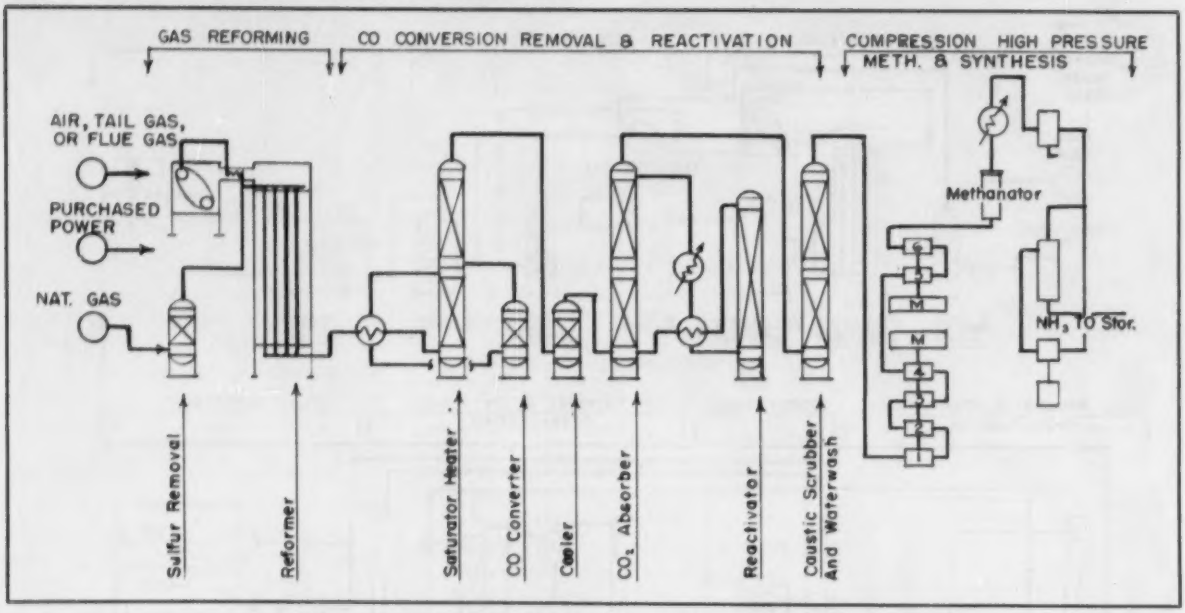



FIGURE 2—Mississippi Chemical Corporation original ammonia plant installation.

scrubber where it is contacted with hot condensate. In this unit sufficient water is vaporized to furnish the necessary steam for the subsequent water gas shift reaction. The saturated gas is then passed through the converter feed-effluent exchanger and is further heated to 700-800 F in a direct gas fired heater before going to the converter.

In the converter the carbon monoxide reacts with steam, in the presence of an iron-chromium catalyst, to form carbon dioxide and hydrogen. The converter effluent is cooled in the feed-effulent exchanger and a direct contact water cooler to about 100 F. This cooled gas is scrubbed with monoethanolamine to reduce the carbon dioxide content to less than 0.03 percent. This purified gas passes through a gas booster to up the pressure to about 15 pounds per square inch gage. This recovers the pressure lost in the conversion and methanation steps and insures the synthesis gas compressors of suction at 9 psig. Since the synthesis gas compressors are designed for a suction pressure of 9 psig any reduction results in lost ammonia production capacity.

Synthesis gas from the booster passes through the methanator feed-effluent exchanger and is further heated to approximately 600 F. in a direct gas fired heater before going into the methanator. In the methanator the carbon monoxide and car-

## Meet the Authors

W. B. Dunwoody

J. R. Phillips

W. B. DUNWOODY, general operations manager for Mississippi Chemical Corporation, is responsible for directing the operation of the Company's Yazoo City, Miss., petrochemical plant and heading its Engineering department. Before taking over as general operations manager, he served Mississippi Chemical first as chief engineer and later as assistant technical director. His experience in the petroleum-processing industry also includes service as an engineer with Spencer Chemical Company and with J. F. Pritchard & Company. A former student at the University of Kansas, he is registered as a professional engineer in Texas and Mississippi.

J. R. PHILLIPS is assistant general operations manager of the Mississippi Chemical Corporation at Yazoo City, Miss. Before joining the corporation in 1952, he was with The Girdler Company, which he served five years, first as operating engineer and later as chief operating engineer. His experience also includes work as technologist and chemist with Shell Chemical Corporation at Pittsburgh, Calif. Phillips is a chemical engineering graduate of Case Institute of Technology.

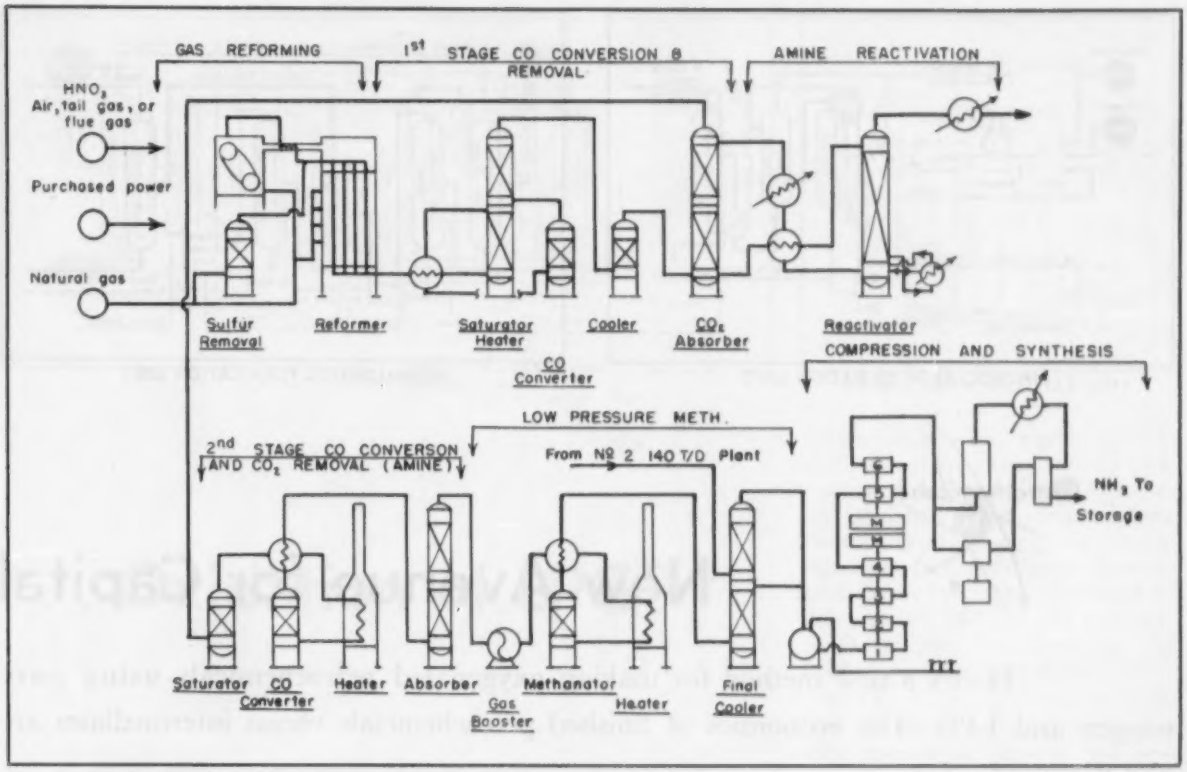



**FIGURE 3—Mississippi Chemical Corporation with low pressure methanation and second stage carbon monoxide conversion.**

bon dioxide react with hydrogen in the presence of a nickel based catalyst to form methane and water vapor.

The methanator gas containing less than 10 ppm of carbon monoxide plus carbon dioxide is cooled in the methanator feed-effluent exchanger and in a direct contact cooler to about 75 F. This final cooling is with a closed system to avoid contamination by carbon dioxide from the cooling water. This closed system water is exchanged against cooling water and ammonia refrigeration.

**TABLE 1**
**Gas Analysis Comparison Table**

| | | PERCENT BY VOLUME | | |
|---|---|---|---|---|
| | | Gas to Compressor Suction (1) | Gas to Copper Liquor (1) | Fresh Gas to Synthesis Loop |
| Conventional Process (Note (1) | $H_2$ | 60.0 | 71.0 | 74.7 |
| | $N_2$ | 20.0 | 23.4 | 24.7 |
| | CO | 3.5 | 4.0 | 25 ppm |
| | $CO_2$ | 16.0 | 1.0 | .... |
| | A + $CH_4$ | 0.5 | 0.6 | 0.6 |
| | Total (Dry) | 100.0 | 100.0 | 100.0 |
| Mississippi Chemical Corporation (original) (Note 2) | $H_2$ | 74.4 | .... | 73.2 |
| | $N_2$ | 23.3 | .... | 24.4 |
| | CO | 1.5 | .... | 10 ppm |
| | $CO_2$ | 10 ppm | .... | .... |
| | A + $CH_4$ | 0.8 | .... | 2.4 |
| | Total (Dry) | 100.0 | .... | 100.0 |
| Mississippi Chemical Corporation (with Low Pressure Methanation) (Note 3) | $H_2$ | 74.1 | .... | 74.1 |
| | $N_2$ | 24.8 | .... | 24.8 |
| | CO | 10 ppm | .... | 10 ppm |
| | $CO_2$ | .... | .... | .... |
| | A + $CH_4$ | 1.1 | .... | 1.1 |
| | Total (Dry) | 100.0 | .... | 100.0 |

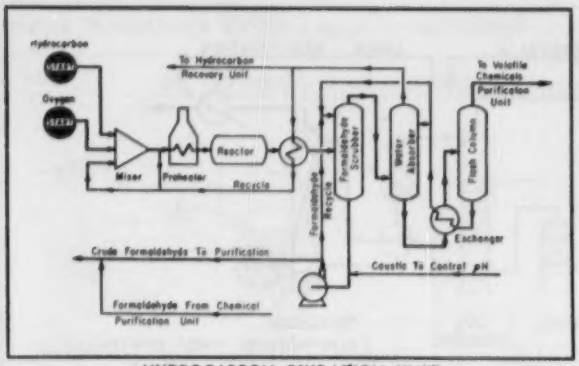
Note 1: Gas under water scrubbing for $CO_2$ removal at 4th stage discharge and copper liquor scrubbing at 5th stage discharge. Volume of useless gas compressed through four stages and lost in circulating water degasifier tower amounts to approximately 40 percent of volume of fresh gas entering ammonia synthesis loop.
Note 2: Gas undergoes methanation at high pressure before entering synthesis loop. Unless gas compressed 6 stages amounts to 6.4 percent of gas actually entering loop.
Note 3: All gas entering compressor suction enters synthesis loop.

**Process Advantages**—The advantages of this low pressure synthesis gas purification for MCC are:

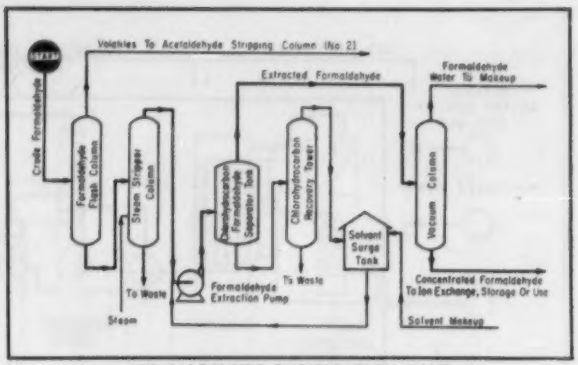
- Increase of over-all ammonia production of about 20 percent.
- Reduction of the gas lost by purging the synthesis loop
- No need of around-the-clock lab service
- Lower investment in purification equipment
- Lower investment in gas compression equipment

The plant investment per annual ton of ammonia produced in the original installation (120 tons per day) was approximately $123. The investment was reduced to $103 per ton by the addition of the low pressure methanation process (on 160 tons per day of additional production). The investment per annual ton of ammonia production for the low pressure methanation system alone was approximately $75 per annual ton. Operating costs including fixed charges for this additional ammonia capacity is less than $20 per ton. ##

'56 Petrochemicals




HYDROCARBON OXIDATION UNIT




FORMALDEHYDE PURIFICATION UNIT

# New Avenue for Capital

**Here's a new method for making oxygenated petrochemicals using pure oxygen and LPG. The economics of finished petrochemcials versus intermediates are also discussed.**

**Ronald E. Meyer**
Remwood Chemical Company
Tulsa

FROM ALL outward appearances the petrochemical industry seems to be suffering from high earnings and shrinking profits. Some of the more obvious reasons for these effects are:

- The fertilizer industry is fast becoming saturated with ammonia plants.
- The synthetic fiber industry has ample stocks and is facing the rapidly returning prestige of cotton and wool.
- Polyethylene is overwhelming the plastics industry.
- There is an abundant supply of new and better type wetting and cleansing agents clouding the detergent field.

Many petrochemical plant executives are casting about to locate new avenues for expansion in order to invest current profits, as well as protect old ones. Those not yet in the petrochemical field, but anxious to get on the bandwagon, are searching for basic processes upon which to build. Foreign petrochemical interests are beginning or expanding their facilities and are also looking for likely ways to do it.

Let's look at the trends in the petrochemical industry for the past 11 years —the changes that have taken place —the adjustments being made because of these changes and the many things still to be done. This article will describe a process that can help solve the growing problem of high earnings and shrinking profits, i.e., the direct oxidation of LPG with pure oxygen to produce petrochemicals.

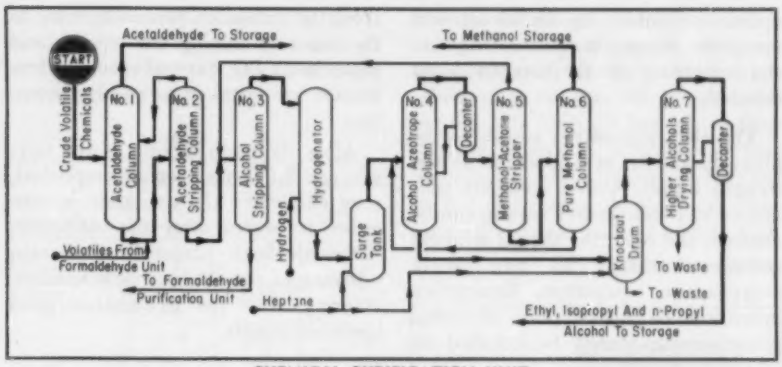
**Intense Competition**—With all industries entering into an era of intense competition, the petrochemical executive knows that new processes must be found that can be built closer to the heavily populated consumer areas. The prime factors behind this trend are:

- The cheap fuel, raw materials and labor that attracted the petrochemical industry to the Gulf Coast has all but disappeared.
- Gas pipe lines from the Southwest are rapidly reaching other sections with cheap and abundant fuel.
- Transportation costs, especially rail and truck, have had tremendous increases.

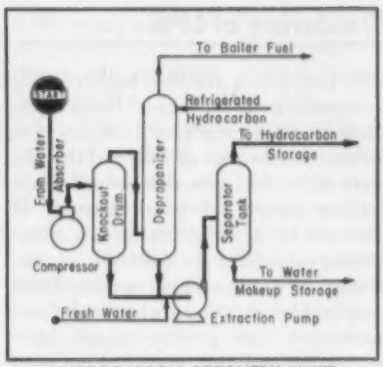
Other factors that prompt management to search for process to locate closer to consumption centers are:

- Selling price is on a delivered basis; transportation costs, sometimes greater than the value of the goods themselves, bite into the profit portion of the selling price.
- Many petrochemical plants show no profit until full capacity operation is attained.
- Increased labor, construction and raw material costs exert their full influence on manufacturing costs.

**Product and Raw Material Contracts**—A few years ago contracts for the entire plant output during the payout period could easily be obtained before construction was even started. This is not true today. Most companies are encountering more resist-




CHEMICAL PURIFICATION UNIT




HYDROCARBON RECOVERY UNIT

# . . . Oxidation of LPG?

ance to supply contracts because of the adequate materials available. This tends to minimize any advantage of a contract. Some large chemical companies in securing raw materials, such as propane and butane, are finding it expedient to contract for not more than 70 percent of their requirements and buy the remainder on a spot basis. Thus they can enjoy the advantage of low priced distress materials.

A firm raw material contract, during the past two years, could and did cost many companies money. They could have purchased their needs on a spot basis much cheaper. Also most petroleum companies are reluctant to write long term, firm price contracts, to supply fuel and raw materials to petrochemical companies. Most petrochemical companies want firm contracts for a major portion of their raw material needs, especially during the amortization period of their facilities, while the petroleum companies do not like to commit themselves for longer than three year periods.

**Payout Time**—Plant payouts are getting longer. For any new capacity the payout must necessarily extend over a longer period. Ten years ago, many new plants could be paid out in one year or less. Now the payout period has gradually lengthened until it is difficult to find new ventures, or to expand existing facilities which, will pay out in less than 5 to 7 years. For example, in a case familiar to the author, the payout was increased from 7 to 27 years merely by increasing the raw material cost from 5½ cents to 6 cents per gallon.

**Plant Locations**—There is a very definite trend to changing plant locations. The southwest is becoming less and less attractive, principally due to high transportation costs.

Since it is impossible to move existing facilities some alert companies are making several marketing changes to better meet competition: For example one of the largest oil companies in the nation is marketing a lower specification alcohol to consumers not requiring the more costly pure grade. In this manner previously competitive products are eliminated. Also, more and more companies are allowing carload or truck load prices on mixed loads of 20,000 pounds or more, on a variety of products. This practice is especially helpful to smaller companies that use several of one suppliers products, and are reluctant to tie up capital necessary to inventory truckloads of each material.

Many companies, having trouble with their profit picture, due to high cost marginal facilities, are looking at the Ohio River Basin and the West Coast as favorable areas for possible expansion. New installations here are advantageous because it is cheaper to transport the fuel gas and raw materials by pipe line than ship the finished products from distant points.

And finally, many companies, both large and small, are rapidly expanding their research facilities to find new uses for old products, and develop new products which will command higher prices and bolster the profit picture.

Since the high cost of transportation and longer payout periods appear to be the most troublesome items in the minds of the executives, methods for overcoming these obstacles should be found. One suggested method for overcoming high transportation costs in the LPG industry is to extract more of the LPG at the consumer end of the pipe lines rather than before they enter. This could be accomplished if the producers would market their product on a heating value basis to the pipe lines, installing only enough equipment in the field to remove the heavy liquids and corrosive materials. Much of the West Texas propane and butane could be marketed to a better advantage in this manner.

Another method for overcoming the transportation bugaboo would be the installation of smaller plants in each large consuming area. Better product distribution would then be attained.

Probably the best way to overcome the long payout of new plant capacity would be to install auxiliary equipment to convert the high volume, low profit basic petrochemical intermedi-

ates into lower volume, higher profit consumer petrochemicals. In most instances these auxiliary facilities will payout in one year or less, and thereby materially decrease the overall plant payout picture. A good example of this will be described later, where the primary products are the high volume, low profit petrochemical intermediates —acetaldehyde, formaldehyde and methanol. For a very minor additional expenditure they can be converted to the increasingly popular low volume, higher profit petrochemicals, such as normal butyl and octyl alcohols, pentaerythritol, the pyridines, vinyl acetate and many others.

The first semi-commercial oxidation process was erected by Cities Service Company at Tallant, Okla., in 1926. This was followed much later by Celanese Corporation's three plants at Bishop, Texas, and Pampa, Texas, and their Edmonton, Canada plant. With the technological advancements made in this process it has become the cheapest route to these three basic oxygenated petrochemicals. For example, $15-17 million investment would be required to produce the acetaldehyde, formaldehyde and methanol by other methods that could be produced in a LPG oxidation plant costing $7-8 million.

One of the foremost technological advancements in the oxidation of LPG has been the use of relatively pure (95 percent) oxygen instead of air. This change resulted in about 30 percent increase in petrochemical yields. Other advantages are:

- Smaller equipment to handle the same volume of hydrocarbons and oxygen.
- No vent loss of LPG compared to 4-5 percent loss in the air process.

The Celanese Corporation is presently expanding their facilities at Bishop by 25 percent with the entire expansion project utilizing pure oxygen rather than air.

## LPG OXIDATION PROCESS

### Auxiliaries and Utilities

**The oxygen plant** is the most important single auxiliary. The reliability of the supply of 95 percent oxygen is essential to the success of the whole LPG oxidation process. The operator should have confidence and complete operational knowledge in the reliability of the oxygen plant selected.

**The electrical energy** supply to the plant is almost as important as the oxygen supply. Unless complete reliability in public power supply can be assured, the operator should strongly consider installing his own power generation equipment. Emergency operation by other than electrical prime movers should be installed on all essential equipment.

### Operating Pointers

**The technique used** in handling the LPG feed stock, the oxygen and the mixing of the two chemicals is very important to the operation of the plant. Proper technique removes the danger normally involved when deliberately creating explosive mixtures. Improper handling of these raw materials can result in serious explosions.

The most important factor in handling the LPG raw material is insuring a constant, uninterrupted flow to the oxidation system. Because of the variations in the physical properties and behavior of LPG due to atmospheric conditions it is best to avoid any mechanical handling equipment. This will avoid vapor-locking, flashing and mechanical breakdowns. By insulating and maintaining a constant pressure on the LPG feed tanks (by pressure regulated steam heater) slightly above that of the oxidation system a reliable and steady feed supply will be assured.

**The 95 percent purity oxygen** usually is available at the oxygen plant at atmospheric temperature and pressure. It must be compressed to several pounds above that of the oxidation system and cooled before going to the oxygen-LPG mixer.

**The good mixing** of the oxygen and vaporized LPG is dependent upon the proper operation of the mixing vessel. This vessel is usally packed with Raschig rings or Beryl saddles to insure good mixing of the gases. If the gases are mixed and kept moving at all times, without dead spaces in the lines, mixing is accomplished without any danger of explosion. To protect against any flow stoppage recycle some of the cool recycle gases from the oxidation system directly to the point of mixing the oxygen and vaporized LPG. Several special safety devices are installed as added protection.

After thorough mixing of the oxygen and LPG has been accomplished, they can enter the oxidation system either before or after the preheater. Although both places have certain advantages, in the author's opinion, entering after the preheater gives optimum results.

**Product Purification**—Depending upon the use made of the petrochemicals manufactured by this process is the complexity of the purification and separation system. If the formaldehyde is being made for captive use it need not be concentrated to commercial specifications. Also, it will not require ion exchange treatment for removal of trace formic acid. If the formaldehyde is prepared for sale it must meet rigid specifications and additional capital must be expended for equipment to finish the product.

Acetaldehyde may be prepared for captive or market use by only one or two columns at most. However, to separate and purify the remaining petrochemicals, i.e., methanol, ethyl, iso- and normal propyl alcohols will require elaborate and expensive series of towers. This purification equipment is described later. If these remaining petrochemicals can be sold or used as a blend, without separation or purification, considerable capital investment and operational expense can be saved.

**Upgraded Products**—Acetaldehyde, formaldehyde and methanol are the three basic petrochemical intermediates and acetone, ethyl, iso and normal propyl alcohols are the secondary petrochemicals produced by a LPG oxidation unit. There are many other products that can be manufactured easily with the addition of other processing units. Among these petrochemicals[2] are: Pentaerythritol, Aldol, Butyraldehyde, Trimethylolpropane, n-Butyl alcohol, Vinyl Acetate, Maleic anhydride and many others.

**Products and Yields**—When oxidizing LPG with high purity oxygen, the petrochemical[2] yields shown in

Table 1 are usually found. The yields in Table 1 are expressed in pounds of petrochemical per gallon of fresh hydrocarbon feed.

**TABLE 1**

| CHEMICAL | YIELD, POUND PER GALLON OF FRESH FEED | | |
|---|---|---|---|
| | Propane | n-Butane | i-Butane |
| Acetaldehyde | 1.80 | 1.6 | 0.75 |
| Formaldehyde | 1.6 | 2.0 | 1.2 |
| Methyl Alcohol | 1.4 | 1.0 | 0.20 |
| Acetone | 0.15 | 0.2 | 1.40 |
| Mixed Solvents | 1.0 | 1.5 | 1.6 |
| | 5.95 | 6.3 | 5.15 |

**LPG Oxidation Unit**—Oxygen and propane or butane are mixed in a ratio of about 1:2, and blended with recycle gases and preheated in a furnace to their ignition temperature (i.e., 670-700 F) at a pressure of 100-150 pounds per square inch. These hot gases flow to a reactor which is merely a long mild steel pipe. However, the size of the reactor is quite critical. It must be long enough to permit complete reaction and consumption of oxygen. It must be of the proper diameter to keep the velocity at the right magnitude. If the diameter is too small, there is incomplete reaction; if too large over-reaction takes place with the formation of carbon and decreased yields of petrochemicals.

As the reaction proceeds through the pipe, the temperature rises to a maximum of about 800-850 F. To obtain optimum yields of petrochemicals this temperature must be kept as close as possible to 800 F. The progress of the reaction is followed easily by spacing thermocouples every four, six or eight feet apart along the entire length of the reactor. Some oxidation reactors have a large packed vessel at the hot end, called a peroxide decomposer. In the author's experience, no peroxides have been isolated, using pure oxygen, and this vessel is unnecessary.

The hot gases are exchanged with recycle gases going back to the preheater. This cools the reactor product to about 300 F and it enters the formaldehyde scrubber and is further cooled to about 140-160 F. Having a short line between the heat exchanger and the formaldehyde scrubber is very important to prevent resin formation and eventual plugging. Formation of resins decreases petrochemical yields.

The relatively cool gases enter the lower section of the scrubber which consists of about 5 baffles and 5 bubble-cap trays. Here the gases are scrubbed with dilute formaldehyde solution (about 4 percent) that enters the top tray from the base of the flash column. Additional scrubbing is done by recycling cooled scrubber bottoms to the top section of he tower. The bottoms concentration is usually built up to about 20-25 percent. During continuous operation, a portion of this crude formaldehyde solution is drawn off to crude storage before going to the purification unit.

Scrubber overhead, minus most of the formaldehyde, is further cooled in a spray cooler and enters the base of the water absorber as a gas. The spray cooler lowers the gas temperature from about 140-160 F to atmospheric temperature. Cooled dilute formaldehyde solution (4 percent) from the bottom of the flash tower enters the top of the water absorber and absorbs the remaining volatile oxygenated petrochemicals from the unreacted hydrocarbon gases. The overhead from the water absorber (hydrocarbon plus $CO_2$, CO and $N_2$) is recycled back through the shell side of the reaction cooler and then to the preheater.

Bottoms from the water absorber, containing the volatile petrochemicals, are exchanged with dilute formaldehyde solution from the bottom of the flash column and feed into the center of the flash column. The flash column is maintained at about 40-50 psi with water reflux. The volatile petrochemicals—acetaldehyde, methanol, acetone and higher alcohols—are flashed overhead and taken to storage to await purification. The stripped bottoms (water) are exchanged with the flash column feed (through the tube side of the exchanger) and returned to the water absorber and scrubber. The portion that goes to the scrubber is to prevent excessive buildup of formaldehyde in the absorber water.

The overhead accumulator of the flash column is connected to a vent scrubber column (not shown on the flow diagram). A small quantity of hydrocarbon is dissolved in the volatile chemicals in the absorber, and is flashed overhead in the flash column. This hydrocarbon, along with some acetaldehyde, can be vented to the atmosphere with some resultant loss of petrochemical yields.

The make-up water for the whole oxidation system enters the top of the vent scrubber which operates at about 10 psi. Here the hydrocarbon and acetaldehyde are separated and returned to the system; the hydrocarbon going overhead and back to hydro-

**Meet the Author**

RONALD E. MEYER graduated from Penn State University in 1932 with a B.S. degree in electrochemical engineering. After working 5 years as a partner in a coal and lumber business, Meyer returned to Penn State in 1937 and was awarded his M.S. degree in organic chemistry in 1939 and his Ph.D. degree in 1941. During this time Meyer became associated with Socony-Vacuum Oil Company in the Research and Development division at Paulsboro, New Jersey, where for 3 years he worked on synthetic lubricants and the Fischer-Tropsch process. He then joined the petroleum chemicals division of Celanese Corporation in 1943 to assist in developing a process for the partial oxidation of LP gases to oxygenated chemicals. This process reached commercial stature at Bishop, Texas, in 1945. In November, 1946, Meyer joined Warren Petroleum Corporation as Research Director to organize a research and development group. He later became manager of the Petrochemical division for that company. In April, 1955, Meyer resigned this position at Warren Petroleum to spend his full time doing consulting work on petrochemicals, and to organize the Remwood Chemical Company, manufacturers and marketers of the modern detergents and liquid fertilizers. At the present time he is president of this company.

carbon storage and the acetaldehyde, dissolved in the water, being returned to the system as make-up water to the absorber, scrubber and reflux to the flash column.

The water absorber overhead is rich in unreacted hydrocarbons having an analysis of approximately—

| | |
|---|---|
| $C_3H_8$ | 69 percent |
| $CO_2$ | 6 percent |
| CO | 14 percent |
| $N_2$ | 5 percent |
| $CH_4$, $C_2H_6$, $C_2H_4$ | 6 percent |

This gas is split into two streams, the major portion being recycled through the reactor cooler to the preheater. The other stream is drawn off to keep the system pressure constant at about 100-150 psi. If this portion were not drawn off the system pressure would build up due to the accumulation of carbon dioxide, carbon monoxide, methane and ethane from the oxidation reaction. Since this gas contains about 69 percent LPG it is reprocessed in the hydrocarbon recovery unit.

An undesirable product of the partial oxidation reaction is formic acid. The small amount that is formed tends to concentrate in the formaldehyde scrubber. While operating under optimum conditions—formaldehyde concentration of 20-25 percent—the formic acid will build up to about 0.5-0.7 percent. Not only is the acid a nuisance because of corrosion, it also catalyzes the formation of acetals and hence the loss of formaldehyde production.

There are two methods that can be used to control this formic acid and each has its own special advantages. Close study of the particular process plant will determine which one is to be used.

**1.** An ion exchange unit[1] may be inserted in the formaldehyde scrubber recycle line. The ion exchange resin continuously removes the formic acid from the crude formaldehyde as it is formed and eliminates the formation of acetals.

**2.** Injection of a controlled amount of dilute (20 percent) caustic solution into the formaldehyde scrubber recycle line. The formic acid, being more acidic than the formaldehyde, will be destroyed with no effects on the formaldehyde.

The second method is generally preferred over the first for several reasons:

- The expensive equipment needed for the ion exchange method.
- Some formaldehyde is lost in draining and washing the ion exchange unit.
- The ion exchange unit required more direct operating labor.

**Hydrocarbon Recovery Unit**—About 20-25 percent of the total quantity of gases passing through the system are vented and sent to the hydrocarbon recovery unit. The recovery unit may be operated in several ways, such as:

**1.** As a gasoline plant in which the LPG is absorbed in oil from the carbon dioxide, carbon monoxide, methane and ethane (known as inerts).

**2.** Bypassing the vented gases through a refrigerated absorber and absorbing with cold liquid LPG.

**3.** The vented gases may be compressed from system pressure to about 500-600 psi, partially condensed in a knockout drum with the vapors going to fractionating column in which the remainder of the LPG is separated from the inerts. The liquid LPG is removed from the separator and the bottom of the fractionating tower, mixed with water and dilute caustic, separated into two phases—water and hydrocarbon. The recovered hydrocarbon is returned to LPG storage and the water solution returned to system water make-up or discarded.

The water-caustic wash is to remove small amounts of chemicals, which, if sent back through the oxidation process would be oxidized further to inerts and thereby reduce over-all petrochemical yield.

The third method, shown above and in the flow diagram, is preferred and recommended for producing the best results.

The inert gases, carbon dioxide, carbon monoxide, nitrogen, methane, ethylene and ethane still have a heating value of 450 Btu and can be mixed with fuel gas and burned in the steam generators supplying steam for the entire plant.

**Formaldehyde Purification Unit**—The crude formaldehyde solution going to the purification unit contains approximately 20-25 percent formaldehyde and from 10 to 25 percent volatile petrochemicals such as acetaldehyde, methanol, acetals, acetone and higher alcohols depending upon the operation of the oxidation unit. The volatile petrochemicals should be held at about 10 percent of the crude products for best results. The crude formaldehyde also contains some heavy ends such as glycols, and glyoxals, etc.

Of the several methods for the purification of formaldehyde products each has certain advantages over the other. The main differences between the processes are:

- Is the product steam-stripped to remove the heavy ends before or after the volatiles are removed, or,
- Is it necessary to steam-strip the heavy ends away at all. In the author's opinion a purer formaldehyde product is obtained by the use of steam stripping after the volatiles are removed.

Referring to the flow diagram, the crude formaldehyde enters the flash column (operating at 10 psi) and the volatiles flash overhead. These overhead products are sent to the hydrogenator for conversion to alcohols or to the column immediately ahead of the hydrogenator. The formaldehyde solution bottoms from the flash column are sent to the steam-stripper and pressure column (operating at about 35-40 psi). This solution enters the column about midway and the steam enters several trays below the feed tray. This insures all the formaldehyde going overhead and the heavy ends being bottom material and discarded. At the same time the formaldehyde concentration of the distillate is increased from 20-25 percent to about 34-40 percent.

To prepare specification grade formaldehyde, the concentrated solution is mixed with a chlorinated hydrocarbon (methylene chloride, perchloroethylene, trichloroethane, or tetrachloroethane) and passed through an extraction pump or sieve jet extractor to a separator tank. The formaldehyde upper layer is transferred to a solvent stripper column then to a vacuum column for further concentration if necessary. The heavier bottoms, chlorohydrocarbons, are sent to a recovery column for cleaning purposes and then to storage and re-use.

If the formaldehyde must be concentrated further than 34-40 percent a vacuum column must be used. The vacuum column operates at about 27 inches of mercury vacuum. The formaldehyde is concentrated in the bot-

tom to about 45 percent. The overhead, containing about 4 percent formaldehyde, is returned to the oxidation unit for re-use as make-up water. Since it is always better for the finished material to be an overhead product from a tower, the bottoms product is ion exchanged (not shown on the flow diagram) to remove the small amount of formic acid formed during the purification process, and then flashed overhead in another column (not shown on the flow diagram) to produce an excellent quality 45 percent formaldehyde. This material may be sold as such or diluted with 7-8 percent methanol for easier shipments over long distances.

If the formaldehyde is to be used for captive purposes, in all probability, the vacuum column and the ion exchanger can be eliminated, thus exercising a considerable savings.

**Petrochemical Purification Unit**—The volatile petrochemical mixture from the oxidation unit contains acetaldehyde, acetals, acetone, methanol, ethyl alcohol, iso and normal propyl alcohols, propionaldehyde, acrolein and about 10 percent water. To separate and purify these constituents requires a series of distillation columns.

Referring to the flow diagram, the mixture of petrochemicals enter the center of column Number 1. This column contains about 70 trays and operates at about 30-50 psi. A small amount of water is introduced into the column near the top to hydrolyze any ethylene oxide that might be present. Good acetaldehyde is taken overhead to storage, sale or use.

Acetaldehyde column (Number 1) bottoms and formaldehyde flash column overheads, both of which contain some acetaldehyde, enter column Number 2 which operates at about 20 psi. Here acetaldehyde is taken overhead and recycled back to column Number 2 for further processing.

Column Number 2 (acetaldehyde stripping column) bottoms, contain everything except acetaldehyde, enters the volatile petrochemical stripping column (Number 3) where all of the volatile petrochemicals are flashed overhead, while the non-volatile formaldehyde in water is removed as bottoms and goes to the formaldehyde purification unit. This stream, while not large, contains approximately 17 percent formaldehyde.

The overhead from the stripping column (Number 3) is heated to about 150-300 F. and enters the hydrogenator which operates between 400 and 800 psi. The hydrogenator tower is filled with ⅛ inch nickel pellets and pressured with hydrogen. The material to be hydrogenated enters at the top and percolates down the column, over the catalyst in the presence of excess hydrogen. All of the aldehydes, ketones and unsaturated compounds are converted into alcohols.

An alternative to hydrogenating the mixture is to sweeten it with caustic before removal of the alcohols. In this case all of the aldehydes are destroyed by converting them to resins which are hard to handle. This practice is expensive and messy and results in lower yields. It is not recommended.

The hydrogenated product is mixed with heptane and fed into the alcohol azeotrope column (Number 4). Here methanol is distilled away from the other alcohols with the heptane overhead into a decanter. In the presence of a small amount of dilute caustic the methanol and heptane separate. The heptane is returned to the column (Number 4) and the methanol goes to the methanol topping column (Number 5).

In the methanol topping column (Number 5), the overhead which contains light ends such as acetal and acetone is returned to the petrochemical stripping tower (Number 3) for further processing. The bottoms are transferred to the methanol finishing tower (Number 6), and the finished methanol taken overhead to storage, sales or use. The bottoms are returned to the alcohol azeotrope tower for further processing. Methanol with a 1 to 4 hour potassium permanganate time is produced in this manner.

The higher alcohols, ethyl, iso- and normal propyl alcohols containing approximately 25 percent water are dried by transferring them from the bottom of the azeotrope tower (Number 4) into a knockout drum and contacting them again with heptane. Most of the water present separates in the drum and is drained off, while the alcohol-heptane mixture is transferred to a higher alcohol azeotrope tower (Number 7), in which the alcohols and heptane are distilled overhead while any water present remains in the bottom of the tower and from there goes to the sewer. The alcohol-heptane distillate separates in a decanter into two layers; the heptane upper layer being returned to the column and the anhydrous alcohol mixture is sent to storage for sales or further processing. This mixture of alcohols is an excellent and inexpensive additive to gasoline to prevent "cold-stalling" of cars in the fall, winter and spring.

**Economics**—The minimum size plant for the production of only basic petrochemicals by oxidation of LPG with pure oxygen should oxidize 35,000 gallons per day of propane or butane and preferably 50,000 gallons per day. If one or more of the high volume-low profit petrochemicals are upgraded into the higher profit consumer petrochemicals the plant size may be lowered to 25,000 gallons per day.

A study of Table 2 and 3 shows that payout time is reduced about 15 percent (Gulf Coast, Mississippi and Ohio River Valley) by combining a 10 million pound per year pentaerythritol plant with a 50,000 gallon per day oxidation plant. The P.E. (pentaerythritol) plant utilizes both acetaldehyde and formaldehyde as raw materials. An even greater reduction in payout time could be shown for a West Coast plant. If, in addition, an adol, butryaldehyde, butyl alcohol, or trimetholpropane unit using acetaldehyde as a raw material is installed the entire plant payout could be substantially lowered still further.

A comparison of the economics for oxidation plants producing basic petrochemicals only, on the Gulf and West Coasts, is shown in Table 2. Gulf Coast production costs for each petrochemical is $0.0182 per pound with payout time of 3.3 years while on the West Coast production costs are $0.023 per pound and payout time is 3.4 years. However, a plant located on the West Coast would be much more economical than is shown by the table due to the intangible transportation rates that are usually absorbed by the shipper.

On paper the Gulf Coast still has a slightly better economic picture than any other area, but being so far from the large consumer markets the lower cost of fuel is more than offset.

There are several very attractive

large consumer areas in the United States that would give competitive advantages to any company locating an LPG oxidation plant there. They are located along the Mississippi and Ohio rivers and on the West Coast. Present facilities supplying the same petrochemicals to these areas are long distances away, such as the lower Gulf Coast and Central Canada, and with cost of transportation rising at a fast rate, a new installation strategically located would place them in a very vulnerable position.


LITERATURE CITED

[1] U. S. Patent, 2,579,847, Dec. 25, 1951.
[2] LPG to Chemicals . . . by Oxidation, Meyer, *Oil & Gas Journal*, June 20, 1955.


**TABLE 2**

**Economic Estimate of LPG Oxidation—Basic Chemicals Only**

**ASSUMPTIONS:**

50,000 gallons propane oxidized per day for 340 days per year. Capital investment—complete with oxygen plant and utilities equals $7.2 million.

| | Gulf Coast | West Coast |
|---|---|---|
| Electricity | .007/kw. hr. | .01/kw. hr. |
| Propane | .04/gal. | .05/gal. |
| Fuel | .16/M cu. ft. | .30/MM Btu |
| Raw Water | .05/M gal. | .20/M. gal. |
| Cooling Water | .015/M gal. | .015/M. gal. |
| **OPERATING COSTS:** | | |
| **Fixed Charges** | | |
| Depreciation 8.33% (12 year life) | | |
| Maintenance 4.0% | | |
| Insurance & Taxes 1.0% | | |
| 13.33% of Capital Investment | $ 960,000 | $ 960,000 |
| **Direct Charges** | | |
| Operating Labor 42 men @ $2.50/hr. | 210,000 | 210,000 |
| Operating Labor Overhead @ 50% | 105,000 | 105,000 |
| Propane | 680,000 | 850,000 |
| Process Chemical & Laboratory Supplies | 40,000 | 40,000 |
| **Utilities & Services** | | |
| Fuel 6,000,000 SCFD | 326,000 | 610,000 |
| Electricity 750 KW | 42,800 | 61,000 |
| Water 1450 gpm | 35,700 | 143,000 |
| TOTAL OPERATING COST | $2,399,500 | $2,979,000 |

**Production**

| Chemical | Yield Lbs./Gal. Propane (2) | Percent Recovery | Production Lbs./Year |
|---|---|---|---|
| Acetaldehyde | 1.8 | 95 | 29,000,000 |
| Formaldehyde | 4.3 | 90 | 66,000,000 |
| Methanol | 1.4 | 95 | 22,600,000 |
| Mixed Alcohols | 1.15 | 74 | 14,500,000 |
| | | | 132,100,000 |

**AVERAGE PRODUCTION COST FOR EACH CHEMICAL:**

**Gulf Coast**

$$\frac{2{,}399{,}500}{132{,}100{,}000} = \$.0182/\text{lb.}$$

**West Coast**

$$\frac{2{,}979{,}000}{132{,}100{,}000} = \$.023/\text{lb.}$$

**Revenue**

| Chemical | GULF COAST Price FOB Plant | GULF COAST Revenue /Yr. | WEST COAST Price FOB Plant | WEST COAST Revenue /Yr. |
|---|---|---|---|---|
| Acetaldehyde | .085 | $2,460,000 | .09 | $2,610,000 |
| Formaldehyde (37%) | .035 | 2,303,000 | .0375 | 2,467,000 |
| Methyl Alcohol 8 | .044 | 995,000 | .049 | 1,107,000 |
| Mixed Alcohols | .044 | 637,000 | .049 | 709,000 |
| | | $6,395,000 | | $6,893,000 |

**Payout Time**

| | Gulf Coast | West Coast |
|---|---|---|
| Gross Revenue | $6,395,900 | $6,893,000 |
| Sales Expense @ 10% | 639,500 | 689,000 |
| Net Revenue | 5,756,400 | 6,204,000 |
| Operating Expense | 2,399,500 | 2,979,000 |
| Gross Profit | $3,356,900 | $3,225,000 |
| Income Tax @ 52% | 1,745,600 | 1,677,000 |
| Net Profit | $1,611,300 | $1,548,000 |
| Net Profit plus Depreciation | $2,211,000 | $2,147,000 |
| Payout Time of Physical Plant | 3.3 years | 3.4 years |

**TABLE 3**

**Economic Estimate for a Combined Hydrocarbon Oxidation and Pentaerythritol Plant**

**ASSUMPTIONS:**

50,000 gallons of propane oxidized per day, 340 days per year, and 10,000,000 lb./yr. P. E. Plant.
Capital Investment;
Oxidation plant, utilities, oxygen plant, and P. E. Plant equals $7,500,000
Mississippi or Ohio River locations with following costs:

| | |
|---|---|
| Electricity | .007/kw. hr. |
| Propane | .04/gal. |
| Fuel | .30/mscf |
| Raw Water | .05/M gal. |
| Cooling | .015/M gal. |
| **OPERATING COSTS:** | |
| **Fixed Charges** | |
| Depreciation 8.33% (12 year life) | |
| Maintenance 4.0% | |
| Insurance & Taxes 1.0% | |
| 13.33% of Capital Inv. | $ 1,000,000 |
| **Direct Charges** | |
| Labor | 340,000 |
| Labor overhead | 170,000 |
| Propane | 680,000 |
| Process Control | 50,000 |
| **Utilities & Services** | |
| Steam, water, gas, electricity | 470,000 |
| TOTAL ANNUAL OPERATING EXPENSE | $2,710,000 |

**Revenue**

| CHEMICAL | Yield Lbs./Gal. Propane | Percent Recovery | Production Lbs./Yr. | Price F.O.B. Plant | Revenue /Yr. |
|---|---|---|---|---|---|
| Acetaldehyde | 1.80 | 95 | 29,000,000 | .... | ..... |
| To P. E. | | | 4,400,000 | | |
| | | | 24,600,000 | .085 | 2,090,000 |
| Methyl Alcohol | 1.4 | 95 | 22,600,000 | .044 | 995,000 |
| Formalin (37%) | | | | | |
| From Propane | 4.3 | 90 | 66,000,000 | | |
| To P. E. | | | 40,500,000 | | |
| | | | 25,500,000 | .035 | 892,000 |
| Other use | | | | | |
| Solvents | 1.15 | 74 | 14,500,000 | .044 | 637,000 |
| P. E. | | | 10,000,000 | .31 | 3,100,000 |
| | | | | | $7,714,000 |

| | |
|---|---|
| Gross Revenue | $7,714,000 |
| Sales Expense @ 10% | 771,000 |
| Net Revenue | $6,943,000 |

**Payout Time**

| | |
|---|---|
| Net Revenue | $6,943,000 |
| Operating Expense | 2,710,000 |
| Gross Profit | 4,233,000 |
| Income Tax @ 52% | 2,200,000 |
| Net Profit | $2,033,000 |
| Net Profit plus Depreciation | 2,658,000 |
| Payout Time of Phys. Plant 2.8 years | |

**TABLE 4**

**Service Requirements for 50,000 Gallons Per Day Propane Oxidation Plant**

| | |
|---|---|
| **GAS** | |
| Reaction Furnace | 540,000 SCFD |
| Boilers | 4,340,000 SCFD |
| Cooling Tower Pump Drivers | 50,000 SCFD |
| Compressors | 1,070,000 SCFD |
| TOTAL | 6,000,000 SCFD |
| **WATER** | |
| Cooling Water | 22,000 gpm |
| Process Water | 425 gpm |
| Cooling Water Makeup | 1,000 gpm |
| **ELECTRICITY** | |
| TOTAL (including Lighting) | 750 K.W. |

# Check List for Superfractionator Design

**Here are 28 design considerations to help you design the best operating and most economical superfractionation column.**

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THE PETROCHEMICAL industry has grown by leaps and bounds in the past ten years. And the picture for the next ten years looks even better. One important factor in the unprecedented growth and success of the petrochemical industry is the role played by superfractionators. The successful and economical application of superfractionators to produce a variety of high purity chemicals accelerated the growth of the petrochemical industry. Product purities ranging from 95 percent to 99.9 percent are now common for typical petrochemicals such as isobutylene, ethylene, benzene, xylene, methyl chloride, butadiene, and cyclohexane.

No commonly accepted definition for superfractionators exists. Verity[1] defined precise fractionation as separation by distillation where at least 30 theoretical trays are employed. Present superfractionators contain from 50 to 300 actual plates.

The use of superfractionators on a large scale is not new. Many superfractionators containing 50 to 70 trays were built in the period from 1936 to 1942 by various oil companies for butane and pentane splitter service.

This article discusses the design, column costs, and instrumentation for superfractionators. The column cost data are useful to process engineers studying economic superfractionation design conditions. By using these data with cost figures on pumps, condensers, reboilers, and refrigerant compressors, the process engineer can establish an economic design basis. Since the instrumentation cannot be divorced from the process design of superfractionators, the process enginer needs some understanding of superfractionator instrumentation.

**Design Factors**—Petrochemical plants often require high purity feedstocks and produce high purity products. Since the number of trays increase rapidly as product purity increases, it is essential to design the column to meet minimum specifications and to produce products of constant composition. The process design of superfractionators does not introduce anything different from conventional fractionators, except greater precision.

**Equilibrium Ratios**—The most critical factor in the design of superfractionators is accurate data on equilibrium ratios or relative volatilities. Because of the close separation involved, a small error in relative volatility becomes magnified in computing fractionation requirements. Smoothed values of equilibrium ratios should be used to establish relative volatilities. Smoothed values of relative volatility should also be used to establish separation requirements. Generalized correlation for equilibrium ratios are inadequate in many cases.

In comparing equilibrium data from various sources, a close check for bubble point and dew point is not a valid test of the data. Even if the calculations check within 1 F, the relative volatilities can still be off. For the ethane-ethylene system a 1 F check still resulted in a 10 percent error in relative volatility. And this leads to a 27 percent difference in number of trays. Experimental data on the actual system involved are therefore highly desirable. It appears that even for a supposedly ideal system as ethane-ethylene, an activity correction factor is necessary for non-ideal liquid at the low temperatures involved. For superfractionation work then, we should try to avoid making any assumption of ideal vapor or liquid behavior.

Rigorous tray-to-tray calculations are not always necessary for superfractionator design. But many major contractors, petrochemical companies, and petroleum companies are, or soon will be, geared to solve such problems with electronic computers using the tray-to-tray approach. The use of electronic computers offers advantages such as establishing the optimum feed plate location, reflux rate and number of trays. For those not equipped with computers, the following procedure can be used for hand computation.

**Minimum Plates**—The Fenske[2] method is generally used to establish the minimum plate requirements for superfractionators. To assure reliable results, the Fenske method is applied over small increments of concentration change. To allow for any inac-

curacy in relative volatilities, extra trays are often used in the final design. The overplus depends on the accuracy of the data, but 10-percent overplus is reasonable even if the relative volatilities are fairly dependable.

**Minimum Reflux**—For many close separations, the feed can be considered to be a binary system and the McCabe-Thiele method used to compute the minimum reflux. In those cases where the desired product consists of several components, the Bachelor[1] method or rigorous plate-to-plate calculations are used. Sometimes, as in the petroleum industry, the fractionation requirements are specified by a true-boiling-point distillation curve. In these cases, the mixture is broken down into narrow boiling range hypothetical components. To use this approach effectively, information on the chemical nature of each hypothetical component is desirable so that proper activity corrections can be applied.

**Final Design**—Frequently, the use of many trays with low reflux ratio is more economical than few plates with large reflux ratios. Calculations can be made to relate the number of plates at various reflux ratios to establish the optimum operating region. But frequently, rule of thumb figures are used to balance first cost and operating costs. Many operations are carried out using only 10 to 50 percent more than the minimum reflux. Low reflux overplus of 10 to 20 percent is used where refrigeration is involved. And higher reflux overplus of 30 to 40 percent is used where cooling water is involved. The Gilliland[4] or Maxwell[15] correlation is used to establish the relationship between operating reflux and number of trays.

**Tray Pressure-Drop**—Since a large number of plates are involved in superfractionators, tray pressure-drop becomes a significant factor in column design. At moderate pressures, a tray pressure drop of about 1.5 to 3 inches of water for a 2-inch weir is reasonable for bubblecaps, perforated trays with downcomers, and round floating disc caps. When the pressure-drop per tray exceeds these limits, the tray efficiency or operating range begins to decrease.

## Meet the Authors

Kiguchi Ridgway

SAM T. KIGUCHI received his B.S. degree from the University of Tulsa, and his M.S. degree from The University of Texas. He has worked in research, process development, and process engineering with Atlantic Refining Company, Socony Mobil Oil Company, and C. F. Braun & Company. At the present time he is senior chemical engineer for C. F. Braun at Alhambra, Cal.

R. L. RIDGWAY received his B.S. degree in electrical engineering from California Institute of Technology in 1937, and is a graduate of General Electric Test Course-10. He has served in various engineering capacities for Union Pacific RR, Bethlehem Steel Corporation, Stone and Webster, and was chief electrical engineer for Canadian Comstock Company for three years. In 1951 he assumed his present position as senior estimator for C. F. Braun & Company at Alhambra, Cal.

Under vacuum conditions, tray pressure-drops of 2 mm to 2.5 mm are reasonable. At lower pressure-drops under vacuum, poor tray performance results. For high pressure operations, a temptation exists to allow more than 1.5 to 3 inches of water pressure-drop per tray. But this increases entrainment. Hence, it is safer to allow a pressure-drop of around 1.5 to 3 inches of water.

**Tray Efficiency**—The plate efficiencies for superfractionators in hydrocarbon service may be computed by the O'Connell[16] method. This method generally gives conservative values. Extensive research on plate efficiencies is now underway by Fractionation Research, and the Research Committee of the American Institute of Chemical Engineers. Plate efficiencies for many superfractionators can be predicted by means of the confidential correlation developed by Fractionation Research Incorporated.

The optimum tray efficiency and range vary with the system involved and the tray design. But in many cases, high efficiencies are maintained from 40 to 95 percent of the flood-point. For bubblecap trays, the tray efficiency does not seem to vary significantly with cap design. But the size and number and arrangement of caps seem to be important.

**Optimum Pressure**—After the column is built, conditions downstream of the superfractionator and refrigeration level sometimes dictate the operating pressure for the column. But in many cases, the operating pressure can be adjusted to suit the installed column.

Clay, et al,[2] show that an optimum operating pressure for maximum product yield from a given column exists for some separations. The optimum pressure depends on the number of trays in the column, the desired separation, and the key components involved. The maximum production of a given purity product depends upon three things:

1. The column capacity generally increases as the pressure is increased.
2. The relative volatility of the key components decreases as the pressure increases, and
3. The plate efficiency increases as the pressure increases.

**Optimum Pressure Check**—The optimum pressure is established by the following stepwise procedure.

1. Minimum plate and minimum reflux requirements are established for several pressures.
2. The relationship between operating reflux and the selected number of actual trays is established from the Gilliland correlation.
3. The production rates at various pressures for the given size column are plotted against operating pressure.
4. The maximum point on the curve is taken as the optimum pressure for the column of a given size and given number of plates.

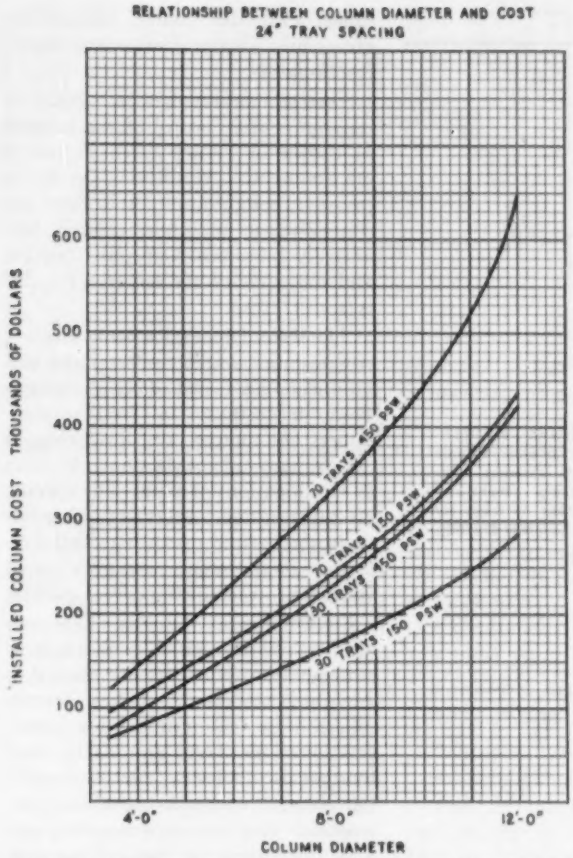


FIGURE 1—Superfractionator column costs for various diameters and number of trays at 24-inch tray spacing.

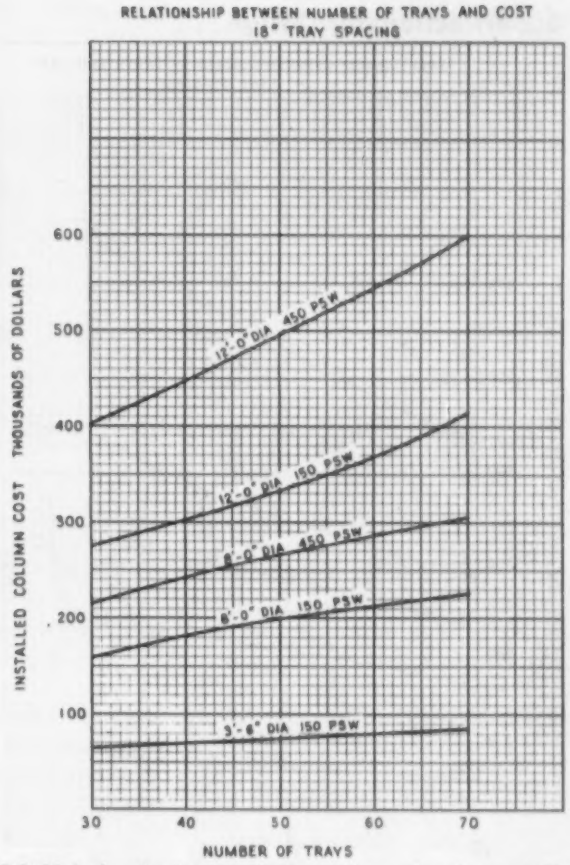


FIGURE 2—Superfractionator column costs for number of trays at 18-inch tray spacing.

Sharper separations show a more pronounced peak on the optimum pressure curve and consequently they require more careful study.

**Column Costs**—Since superfractionators involve a large number of plates, the factors affecting column costs are worthy of careful study. In this section, column costs and the factors that affect column costs are discussed. Total installed costs are given so that they can be used in conjunction with condenser, reboiler, and pump costs to evaluate the effect of various design variables on overall costs.

Figures 1, 2, and 3 show the installed cost for steel columns 42-inches, 96-inches, and 144-inches in diameter. Figures 2 and 3 show that additional trays are cheap for 3-foot 6-inch columns, but not for 8- and 12-foot columns. All the column costs are based on welded-in bubbletrays. The erection costs assume that the column can be completely shop fabricated and shipped in one piece to the plant site. The cost figures include the cost of the foundation, two inches of insulation, ladders, and platforms. The installed costs are approximate because of variations in area costs, business cycle, and customer specifications. The platforms include a 180-degree platform at each of three manholes and a small top-head landing. Access is by a caged ladder from grade to the top-head landing.

**Bubblecap Costs**—The cap cost figures are based on cast-iron caps. Pressed steel caps cost about twice as much as cast-iron caps. But this difference is within the accuracy of the installed cost figures.

**Piping**—Sufficient pipe and pipe-supports are included to tie the feed, product, and utility piping into the assumed existing pipeway located not more than 50-feet from the column.

**Engineering**—It is assumed that engineering, design, purchase, and erection is performed by the engineering-contractor. And the costs include all other charges normally incurred by the contractor.

**Auxiliaries**—Pumps, drivers, reboilers, condensers, and accumulators are not included. Foundations and installation costs for these items are not covered either. The cost of a condenser structure is also excluded.

**Column Size**—The maximum size for shop fabricated columns depends on the location of the fabricator's shop relative to the plant site. There are no size limitations for water shipments. But there are some general rules that can be used as a guide for rail shipments. Columns not over ten feet in diameter, and not over 100 feet in length can probably be shipped anywhere in the United States. Columns up to twelve feet diameter can usually be shipped.

A traffic check should always be made before finally selecting the column. Diameters in excess of twelve feet cannot usually be shipped in one piece by rail. The maximum length of columns for shipping is a function of the diameter. The smaller the diameter, the greater the permissible

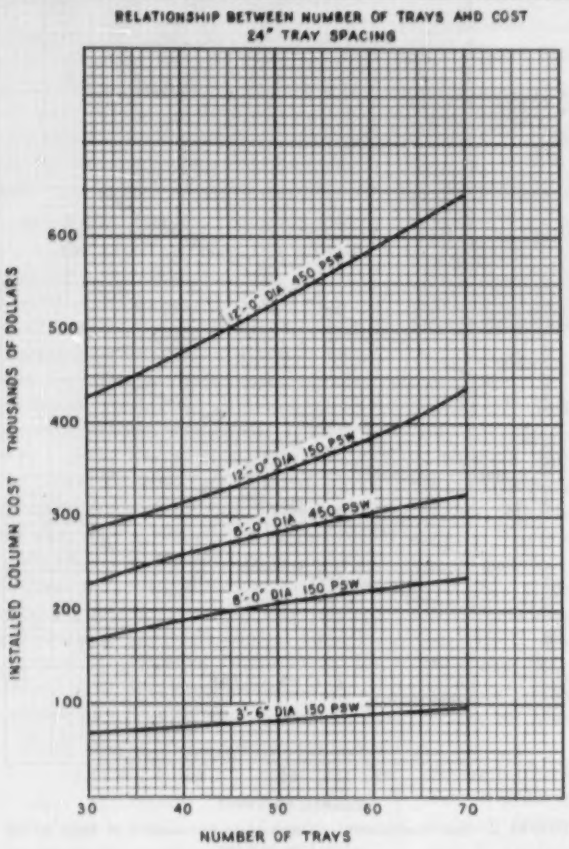


FIGURE 3—Superfractionator column costs showing relationship between number of trays for 24-inch tray spacing.

length. The maximum length is about 160 feet for 3- to 4-foot diameter columns.

**Column Weight**—The maximum shipping weight for loads carried on a single car is 200 tons. For loads carried over two or more cars, any weight over 300 tons requires careful checking with the railroads. These limits apply to rail shipments. If the plant site is served by a waterway, a particular fabricator can make barge shipments exceeding the foregoing limits.

**Other Limitations**—Although columns up to 160 feet can be shop-fabricated and shipped to the plant site, other factors frequently limit the column length to something less than 160 feet. Some typical limitations encountered in the past include plot clearance, aviation hazard, and derrick capacity. To avoid excessive column heights, superfractionators are often built as split towers.

**Tray Spacing**—Tray spacing affects column height and costs directly as shown in Figures 2 and 3. For superfractionators with many trays, the tendency is to use 18- or 20-inch spacing instead of 24-inch. The use of 18-inch spacing could save about 35 feet in column height over 24-inch spacing for a 70-tray column. But a larger column diameter is required where vapor load is controlling because of the lower allowable vapor velocities for closer tray spacing. For small bubblecap columns around 4 feet in diameter, the premium for 18-inch spacing is roughly 6 inches larger in diameter. And for columns around 12 feet in diameter, the premium is roughly 18 inches in column diameter. The premium for closer tray spacing amounts to $2000 for the 4-foot column and $33,000 for the 12-foot column based on columns designed for 150 psig.

**Instrumentation**—Since it is advantageous to design superfractionators to barely meet product specifications, accurate control of the column is essential to minimize product losses. This requirement introduces some significant differences between the instrumentation for conventional and superfractionation columns. Two basic control schemes are commonly used to instrument superfractionators.

One scheme involves inferential or environmental control of the column as shown in Figure 4. In Figure 4, environmental conditions such as pressure, temperature, and flow are controlled to maintain column balance by inference. Constant feedrate and feed quality are essential for this type of control.

The second general scheme involves composition control to keep the column in balance regardless of fluctuations in feedrate or feed quality. Superfractionators are instrumented according to one of the above schemes or modifications of them. The specific instrumentation selected depends upon the desired operating flexibility, process requirements, and anticipated variations in feedrate or feed quality.

**Environmental Factors**—Fractionation variables such as pressure, temperature, and flowrates are classed as environmental factors. These factors establish the environment for superfractionation. They are rarely used for precise column control today. Differential vapor-pressure and differential temperature controllers are sometimes used in the column but this is considered as a modified environmental or inferential control scheme. Temperature control is sometimes used in those rare cases when a 2 F variation is significant enough for column control. But this, too, is classed as a modified environmental or inferential control scheme.

**Inferential Control**—Under inferential control, the products are controlled independently and the boilup rate is held constant. Figure 4 shows the typical instrumentation for inferential or environmental control. Where suitable stream analyzers are not available, this type of volume control remains as a good standby provided a large feed tank is used. Due to the difficulty of keeping the column in balance with fluctuating feed composition, large feed-storage tanks are desirable to minimize composition changes once the column is lined out. Two storage tanks can often be justified to accumulate adequate feed, to allow ample time to analyze the feed, and to minimize tank stratification. This arrangement provides some flexibility to take upsets from the unit ahead of the column without propogating any upsets.

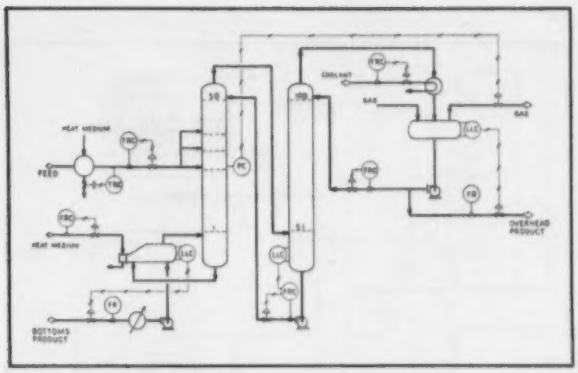


**FIGURE 4—Instrumentation flow diagram showing inferential control of a split-superfractionator.**

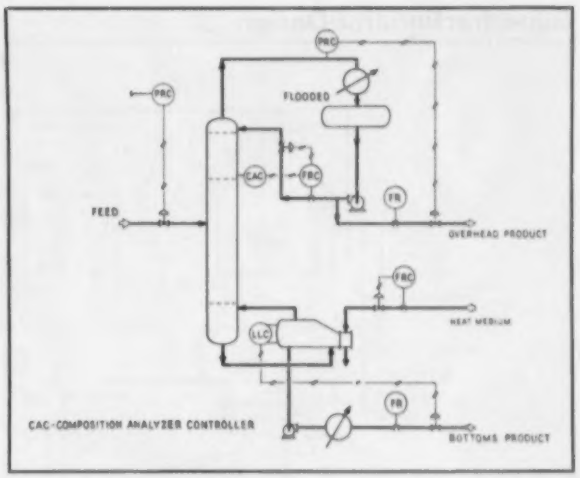


**FIGURE 5—Instrumentation flow diagram showing typical composition control of rectifying section.**

By eliminating the problem of varying feed composition, the column operates essentially with constant feed input and the instrumentation proves entirely adequate.

**Temperature Control**—A temperature controller is sometimes used to take care of fluctuations in feed composition. This is satisfactory for superfractionators provided a 2 F to 3 F temperature difference represents a significant variation in composition. The control point in the column is usually taken in the section with the maximum temperature gradient. The addition of a controller to regulate the reboiler heat supply provides the necessary control to keep the column in balance regardless of any reasonable fluctuations in feed conditions.

**Composition Control**—For many superfractionators, environmental control is inadequate because the feed composition cannot be conveniently controlled ahead of the superfractionator. The use of composition analyzers offers significant advantages in this case. Since the analyzers provide direct information on stream composition changes, they can keep the column in balance regardless of fluctuations in feedrate or feed quality. And on startups, they help to attain maximum product purity without waiting for laboratory results.

These analyzers also eliminate the large intermediate storage tanks required with volume control instrumentation. All of these benefits add up to less product loss and lower superfractionator investment costs to meet minimum product quality.

**Analyzers**—Either the main component or the impurities in the stream can be used for column control. The common composition analyzers available today include the following instruments.

- Continuous refractometers.
- Mass spectrometers.
- Infrared analyzers.
- Ultra-violet analyzers.
- Specific gravity controllers.
- Vapor-phase chromatographs.

The chromatographic instruments operate on a 15-minute cycle, but this is adequate for many applications. One disadvantage with composition analyzers in general, is that specialized skill is required to commission and service these instruments. Some instrument suppliers include accessories and the cost for commissioning their instruments in the price. This factor should not be overlooked in selecting or comparing various instruments.

**Composition Control Point**—Williams, et al[5] show that top plate sampling provides the best control. Intermediate plate sampling offers a large composition change for control, but this advantage is offset by the instability introduced through fluid-flow lag between the plates.

If the column in Figure 5 were operated without composition control, variations in feed composition would upset the column because of the change in feed vaporization at constant feed temperature. The use of a composition controller alone will compensate for changes in feed rate, but will not maintain constant product quality where the reflux ratio is critical. Since the boilup rate is constant, the reflux ratio increases for a decrease in feedrate and a better split results between the top and bottom products. And the reverse occurs for an increase in feedrate.

**Limitations**—Williams, et al[5] also point out that the main disadvantage of top plate control is the low instrument dead time or high sensitivity required for effective control without oscillations. Intermediate plate sampling is more desirable in case a large controller dead time exists.

**Variable Feedrate**—In Figure 7, a feed controller and a composition analyzer are used. The feed controller is cascaded on the reboiler heat-medium flow controller, and the analyzer is cascaded on the product flow controller. The reboiler controller serves to balance column flows, and the composition controller serves to maintain product quality. Cascade control is generally used with composition controllers to achieve stable control.

**Instrument Flowsketches**—The instrumentation shown on the various sketches represents typical controls. The key requirement for inferential control is that the column be controlled primarily for constant material balance. For composition control, the key feature is the use of a composition controller to keep the column in balance. Other control features such as column-pressure control and level control may apply to both types of control schemes.

**Pressure Control**—Figures 4, 5, 6, and 7 show typical methods for con-

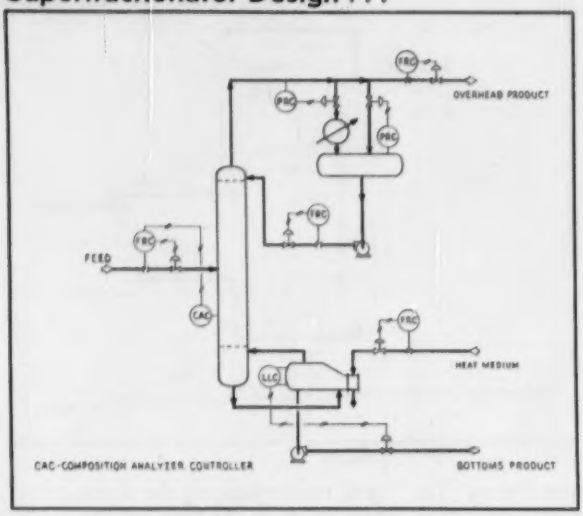


FIGURE 6—Instrumentation flow diagram showing typical composition control of stripping section.

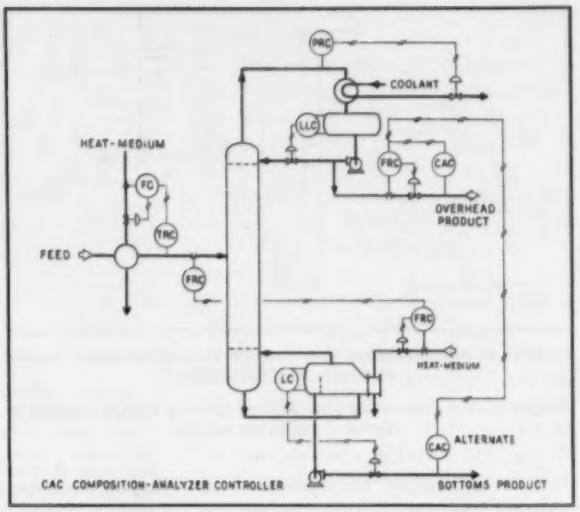


FIGURE 7—Instrumentation flow diagram showing typical composition control of overhead or bottoms product.

trolling column pressure. In Figure 4, inert gas is injected into the accumulator, and the column pressure is controlled by regulating the inert gas bleed.

In Figure 5, the pressure is controlled by flooding the condenser. This control is satisfactory, provided the lag in changing the liquid level is not large. The lag can be reduced by using a pressure control valve between the condenser and the accumulator. But this adds a level controller on the accumulator to control the product flow valve.

As another modification of flooded condenser operation, the pressure controller in Figure 5 can be arranged to reset the reboiler heat-medium with the overhead product on flow control. However, this is not too good for superfractionators because of the thermal lag in the reboiler and the lag across the entire column. In any case, the condenser bundle must be designed to provide reasonable changes in exposed surface area for the flooded condenser system to work satisfactorily.

In Figure 6, a control valve is used in the vapor-line to the condenser. A bypass line around the condenser is sometimes used to minimize reflux temperature fluctuations, and to maintain some back pressure in the accumulator. Reflux temperature fluctuations can be troublesome in superfractionators because of the resultant fluctuations in reflux ratio.

In Figure 7, the column pressure is controlled by regulating cooling-water flow. This method is satisfactory where noncondensibles are absent. If a small amount of noncondensibles are present, they can be vented continuously. Regulation of cooling-water flow is not recommended where the top temperature exceeds 150 F. At temperatures above 150 F, there is the risk of overheating the water and fouling the condenser.

**Level Control**—Figures 4 and 7, show several methods for using liquid level controllers on superfractionators. Figure 4 shows both products on liquid level control. Most superfractionators use reboiler level control on the bottoms product. Level control of the overhead product has the advantage that variations in vapor rates are not transmitted directly to the reflux rate. On the other hand, level control of reflux, as in Figure 7, offers control of reflux ratio in case the feedrate or composition changes.

Figure 4 also shows column level control on the intermediate reflux stream. Here cascade control of level and flow is advantageous because it offers more stable control during startups and upsets, but this cascade system is not always justified.

**Effect of Holdup**—Williams, et al,[8] point out that large condenser holdup tends to destabilize the column except in certain cases. Whereas, large reboiler holdup tends to stabilize the column.

**Instrumentation Costs**—Installed costs for inferential instrumentation, as shown in Figure 4, runs about $40,000 to $50,000 based on board-mounted recorder-controllers. The installed instrument costs for composition analyzers run anywhere from $1,000 to $10,000, depending on the instrument involved and complexity of the analysis involved. These figures do not include the controlhouse.

Controlhouse costs vary from $15 to $35 per square foot depending on architectural treatment and features such as air-conditioning, ventilation, and heating.

The length of the controlboard sets the controlhouse size. For miniature instruments, 20 non-graphic instruments per 4-foot of panel is reasonable. For conventional instruments, 4 nongraphic instruments per panel is reasonable. For graphic panels, 1.5 instruments per running foot is reasonable.

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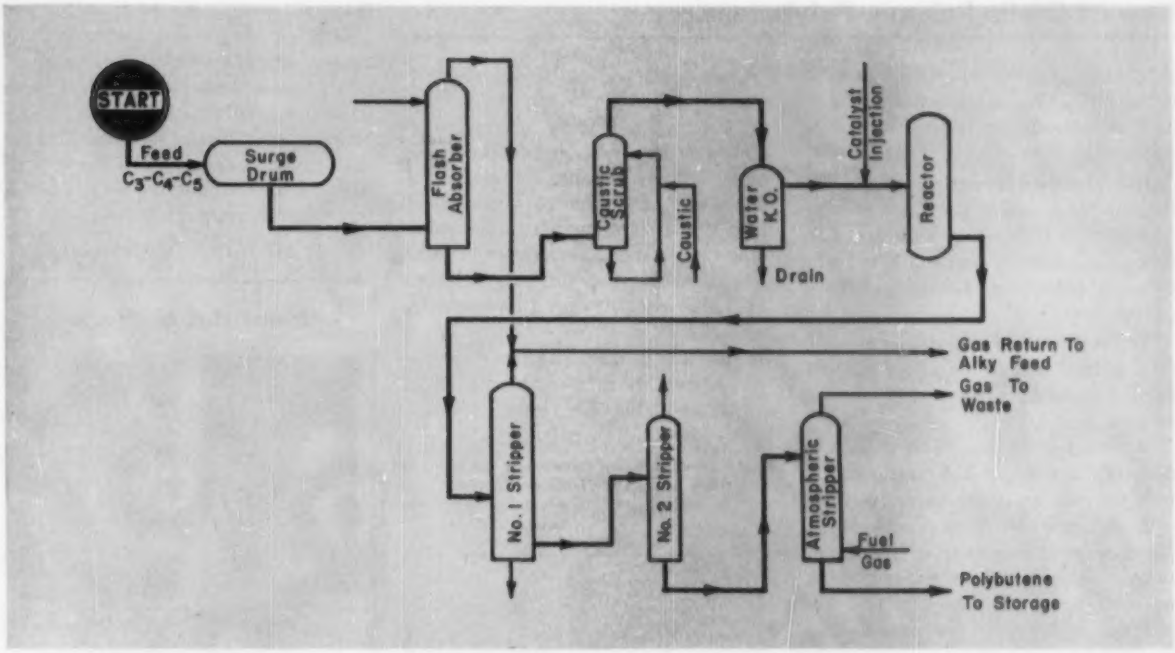


FIGURE 1—Cosden Petroleum's Polybutene unit.

# Newest Olefin Polymer-Polybutene

**These operating data will give you a bird's-eye-view of the process used by one of the world's largest producers.**

**Dewey Mark and Allen R. Orr**
Cosden Petroleum Corporation
Big Spring, Texas

"POLYISOBUTYLENE" normally refers to semi-solid and solid polymers possessing rubber-like properties, whereas "polybutene" is used to identify the viscous liquid polymers.

Just prior to World War II Oronite Chemical Company, recognizing the potential of low molecular weight polybutenes as important ingredients in calking and sealing compounds, pressure sensitive adhesives and as viscosity index modifiers for lubricating oils, constructed West coast facilities to produce viscous liquids ranging from 64 SSU to 19,000 SSU at 210 F. Subsequently similar facilities were constructed by Standard Oil Company (Indiana) at Wood River, Illinois, and El Dorado, Arkansas.

The polymerization of olefin compounds in the presence of Friedel-Crafts type catalysts has been known since the early 1800's. Among the early workers was Berthelot who studied the polymerization of styrene, amylenes and other olefins using both $BF_3$ and sulfuric acid. Butlerov and Gorianov were perhaps the first to prepare high polymers from isobutylene. Research continued through the ensuing years, but it was not until the last twenty-five years that processes were developed for commercial utilization of this research.

The work of Otto and Muller-Cunradi of I. G. Farbin in 1933 disclosed the polymerization of isobutylene at -40 to -80 C in the presence of $BF_3$ in good yields to produce solid products of high molecular weight. At the same time Waterman reported the preparation of viscous liquids and semi-solid polymers by the action of $AlCl_3$ on isobutylene and other olefins at low temperatures.

Commercial quantities of polyisobutylene were introduced shortly thereafter in Germany under a trade name. The Standard Oil Company of New Jersey first introduced similar polyisobutylenes in the United States under a trade name.

Several years ago the Cosden Petroleum Corporation began to investigate the polymerization of isobutylene. Other processes involved polymerizing relatively pure isobutylene dissolved in an inert solvent such as butane and catalyzed by a Lewis-acid. Cosden postulated that the components, other than isobutylene, in a typical feed stock to a phosphoric acid-type polymer gasoline plant, would be relatively inert. The initial postulation also included the use of the above stream, saturated with water; anhydrous $AlCl_3$ as a catalyst; and hydrogen chloride as an activator. Even though many mechanical modifications were incorporated into pilot plant work, the original theory of

producing polybutene was found to be sound. The construction of a 1 million gallon per year plant was initiated.

**The Cosden Process**—A simplified flow diagram of the Cosden Polybutene Unit is shown in Figure 1. The process is relatively simple and straight forward, consisting essentially of three parts:

**1.** Feed preparation—Here the feed is fractionated to adjust the desired components total feed to the reactor.

**2.** Reactor section—This section is basically a tank and a refrigeration unit for reaction temperature control.

**3.** Purification—This portion of the plant consists primarily of fractionation to separate the polymer from the unreacted components.

Fresh feed to the unit is a $C_3$, $C_4$ and $C_5$ fraction from an HF Alkylation unit feed. From the feed surge drum, this mixed feed is charged to a flash-absorber column which adjusts feed stock to maximum reactive components. The bottom product from this tower is then caustic scrubbed for sulfur removal in a regenerative caustic system and cooled to condense excess water which is removed in a water knock-out drum.

From the water knock-out drum, the total feed is refrigerated and sent to the reactor. A slurry, made up of anhydrous aluminum chloride and inert liquid carrier, is injected into the feed stream along with either gaseous HCl or liquid chloroform as a catalyst activator. The temperature in the reactor is controlled to produce polymer of the desired viscosity. The reactor products are pumped to the number one stripper.

Light hydrocarbons from the number one stripper overhead are returned to the alkylation unit feed with the absorber overhead. The concentrated product is charged to a second stripper for more complete stripping of the polymer. Finally, the polymer is stripped in an atmospheric stripper using fuel gas to complete the purification of the product. The finished polybutene is pumped from the bottom of the final stripper to storage tanks ready for loading and shipping.

Heat of reaction in the process is approximately 906 Btu per pound of polybutene. In order to produce various types of polymer, reactor conditions are varied considerably. The following table lists design conditions for a high viscosity and a low viscosity polymer.

**Operating Conditions**—The operating conditions must be varied as shown in Table 1, to make the different viscosities of polymer.

**TABLE 1—Operating Conditions for Making High and Low Viscosity Polymer**

| | High Viscosity | Low Viscosity |
|---|---|---|
| Reactor Pressure, Psia | 5 | 10 |
| Fresh Feed to Reactor, gal/hr. | 809 | 1701 |
| Total Feed to Reactor, gal/hr. | 1,262 | 2,673 |
| $AlCl_3$ Consumption, lb/day | 127 | 300 |
| Chloroform lb/day | 10 | 20 |
| Polybutene gal/day | 1,655 | 3,595 |
| Polybutene lb/day | 12,504 | 25,751 |

**Product**—Cosden polybutene is basically a linear polymer, with molecular weights varying from about 660 to 1520. Many molecules apparently contain only one terminal double bond with minimum cross-linking. Such a highly saturated polymer is stable, does not depolymerize readily under normal conditions and is not subject to atmospheric oxidation. Polybutenes do not harden, set or "dry" nor become waxy or gummy even after prolonged storage. Viscosity and tackiness increase with an increase in molecular weight. Excellent color, almost water white, extreme clarity and bland odor are important properties.

Physical properties of some of the polymers are given in Table 2.

**Applications**—Polybutenes are soluble in petroleum and coal-tar naphthas, both aliphatic and aromatic chlorinated hydrocarbons, lubricating oils, ether and certain esters. Solubility in low molecular weight alcohols, aliphatic ketones and most highly polar solvents is poor. Polybutenes can be pigmented and emulsified.

Important industrial applications of polybutenes include the manufacture of calking compounds, sealants, adhesives, vibration dampeners, surgical tapes, mastic cements, electrical insulations, coated papers, drawing compounds, and special lubricants. Due to its compatibility, polybutenes can be used in conjunction with various resins, gums, rubbers, waxes and asphalts. ##

**TABLE 2—Physical Properties of Various Molecular Weight Polybutene Polymers**

| Molecular Weight (Avg.) | 660 | 700 | 780 | 940 | 1,410 | 1,520 |
|---|---|---|---|---|---|---|
| **Viscosity:** | | | | | | |
| S.S.U. at 210 F. | 375 | 540 | 1,010 | 3,000 | 15,000 | 20,000 |
| Spec. Grav. (Approx) | 0.87 | 0.88 | 0.88 | 0.90 | 0.91 | 0.92 |
| Pounds per Gallon | 7.24 | 7.33 | 7.33 | 7.49 | 7.58 | 7.66 |
| Flash Point (Tag) F. | 280 | 295 | 360 | 500+ | 500+ | 500+ |
| Color, Gardner 1933 | 1+ | 1+ | 1+ | 1+ | 1+ | 1+ |

## Meet the Authors

Mark

Orr

DEWEY MARK, manager of chemical sales, Cosden Petroleum Corporation, Big Spring, Texas, was born in 1925 in Denton, Texas, and received his B.S. degree in chemistry from North Texas State (Denton) in 1943. After three years naval service, he returned to N.T.S.C. and in 1947 received his M.S. degree in organic chemistry. He attended Indiana University graduate school from 1948 to 1952, then joined Cosden as a research chemist. Mark is a member of Sigma Xi, Phi Lambda Upsilon, Phi Delta Kappa and the American Chemical Society.

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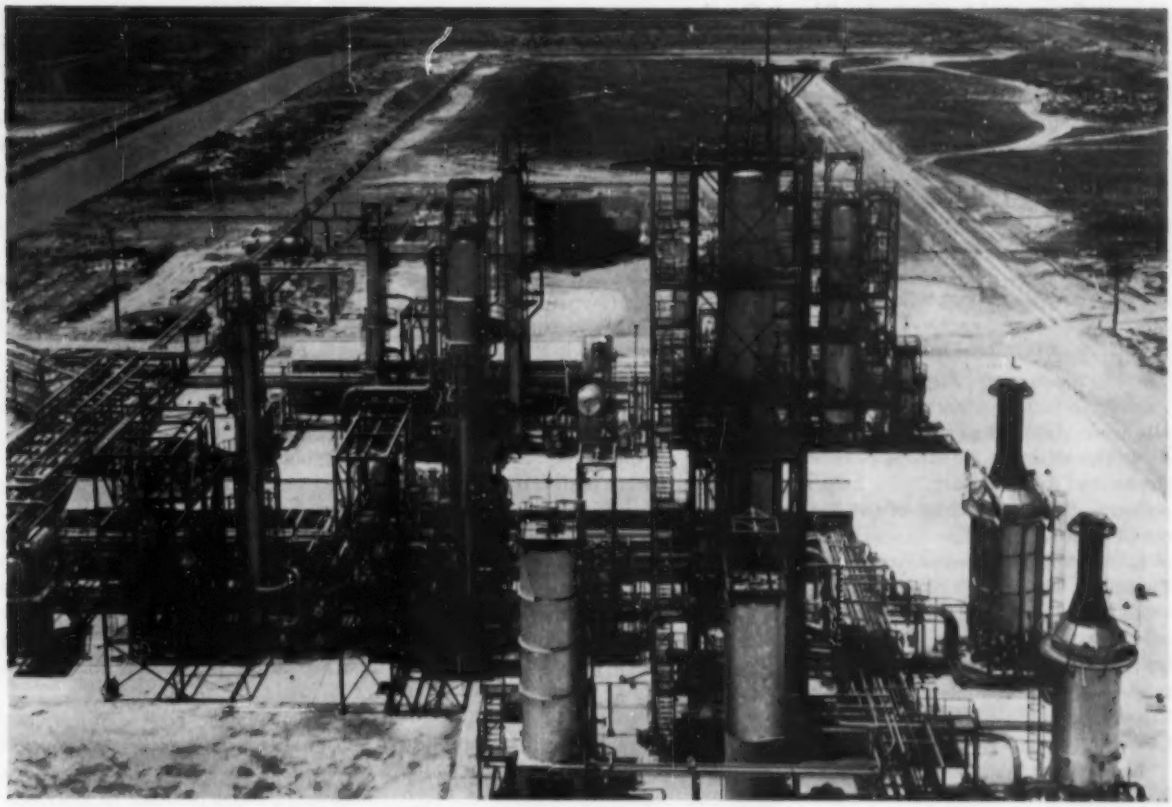
ALLEN R. ORR, who is now chief process engineer with Cosden Petroleum Corporation has been engaged in process work since he started with Big Spring, Texas, refining company in 1950. He joined the company as a process engineer following graduation from Texas Technological College where he received a B.S. degree in chemical engineering. In addition to his duties as chief engineer, which requires considerable attention to work with lighter hydrocarbons in polymerization and alkylation processes, Orr doubles as foreman of the refinery's fluid catalytic cracking unit.



Section of typical petrochemical manufacturing plant.

# Don't Forget Markets in Plant Design

Petrochemicals 36

**Backing up purely technical skills with an engineering philosophy oriented to 'Market Concept' will result in engineering plants and processes that have flexibility, adaptability and convertibility.**

**F. Drake Parker and H. R. Jones**
Arthur G. McKee & Company
Cleveland

THE TECHNOLOGY of petroleum refining has always been dictated by the market demand. Until recent years, however, the trends of market growth, process yields, and product quality, have been gradual, and marketing and economic groups could generally chart the path for engineering to follow. Technological developments, such as thermal cracking, had effects of degree rather than direction. Engineering, therefore, could be carried on satisfactorily with but routine consideration of market and economic factors.

Present day market demands on the refiner are so pressing as to yield and quality, so rapidly changing and so competitive as to selection of product outlet—whether in conventional fuels and lubricants or in petrochemicals—that it is essential that market and economic information be an integral part of design considerations. This we call "The Market Concept" in refinery and petrochemical plant engineering. The practicing engineer must broaden the scope of his thinking to include the "Market Concept" in the design of process units so that they serve not only their nominal purpose, but are flexible, adaptable, and convertible, as may be required to meet rapidly changing market situations.

Prior to World War II refiners were engaged in getting the greatest amount of usable products from a barrel of crude oil by means of thermal processes. Octane number requirements of the automobiles had increased comparatively little over the years since they had become the principal user of petroleum products.

Vapor pressure of the gasoline was varied according to season, which caused fluctuations in the butane and natural gasoline markets. Thermal and catalytic polymerization processes were a means for using the excess butane fractions during warm seasons. Thus the principal determinant of product distribution was the seasonal demand for motor and heating fuels.

During this period few lubricants were compounded with non-petroleum products. Automobile motor oils were changed at frequent intervals. The demand for steam cylinder stocks by the railroads also helped consume the heavier part of the barrel of lube crude. The manufacture of lubricating stocks employed mainly thermal processes which limited the crude stocks for lubricant manufacture to certain types. Unless the refiner enjoyed a source of these crudes he was unable to compete in the lubricating oil market of that time.

The World War II aviation gasoline program boomed catalytic cracking from a fixed-bed, semi-continuous operation to a fully continuous one capable of maintaining its catalyst at high efficiency. Catalytic reforming, born just prior to the war, proved to be a means of utilizing the heavier, low-octane portions of the gasoline in the crude. It has blossomed into a "must" process in any refinery. Catalytic polymerization and catalytic alkylation have proven to be a very profitable means of converting high-vapor pressure, high-octane light ends into high-octane, low-vapor pressure gasolines. Catalytic isomerization, born during the wartime emergency as a means of converting normal butane to isobutane for alkylate production, is presently emerging as means of converting low-octane hydrocarbons into higher octane blending stocks.

Our present petroleum product market is largely the result of the increasing demand of internal combustion engines for more fuel with less tendency to pre-ignite with the increased speed and compression ratio of the engine. It was the demand of the refiner's market which caused him to progress from the batch still to the fractionating column to thermal and catalytic cracking. These units represent progressively greater capital investment and consequently more thought must be given to investment payout before they are installed.

Paralleling the rise in demand for higher octane numbers has been the advent of the jet engine and the phenomenal growth of the diesel engine, particularly its use in transport vehicles. Jet fuels consume some low octane heavy naphtha and kerosine fractions. Diesels have increased the demand for the heavier portion of the kerosine and the light virgin gas oils. As diesel engines have been improved they have been designed for higher speeds. This has increased the demand for lighter fuels of higher cetane numbers and for lighter lubricants.

The diesel locomotive has virtually replaced the steam locomotive. This has caused periodic surpluses of heavy fuel oils. Refiners have been forced to seek more profitable means of fuel oil disposal than consumption as fuel in refinery furnaces. For many refiners, residuum coking has taken care of the fuel oil glut. Coking increases the supply of gas oils available for catalytic cracking and produces coke which, under certain conditions, has a ready market in the manufacture of electrodes for the aluminum industry.

Since the changes which were incorporated into thermal processes were only changes in degree and not of a fundamental nature, they were not rapid. The rate of obsolescence of a thermal unit was determined largely by the service life of its component parts. This permitted the use of periods of ten years or more in amortizing process equipment.

This is not true when catalytic processes are employed. The very nature of a catalyst enables one to constantly improve upon it, and a new catalyst may make an old one obsolete in a very short time. Such developments are accentuated by changes in market demand. The present demand for high-octane gasoline components makes it necessary that the refiner fractionate his stocks very carefully and process the various fractions individually. This quickly makes older fractionating equipment obsolete. Technological obsolescence makes it necessary for the refiner to scrap units long before their normal service life is reached. This shortens the period of time in which capital investment must be amortized.

The petrochemical industry was also a "war baby." While there were some chemicals being produced from petroleum base stocks prior to World War II the number was limited and volume small by today's standards.

Modern petrochemistry dates from the synthetic rubber program of World War II. Cut off from normal sources of crude rubber latex, the nation was forced to turn to synthetic GR-S rubber formed by the copolymerization of butadiene and styrene. Butadiene was produced by the dehydrogenation of butane or butylene. Benzene was recovered from the product of the hydroformer, alkylated with ethylene, then dehydrogenated to styrene. Hydroforming was also important as a source of toluene for explosives. From these developments has grown the petrochemical industry of today.

Petrochemicals now compete for the same components as are required for modern fuels and lubricants. For instance, propylene may be polymerized to motor fuel, or converted to the tetramer which is used in the manufacture of synthetic detergents. Butylene may be alkylated to make aviation or motor fuel or it may be dehydrogenated to butadiene for synthetic rubber. Benzene, toluene, and the xylenes which are produced by catreforming are excellent blending agents in motor fuel. They are also much in demand as intermediates in chemical manufacture. Almost any material which is of value as a base for the manufacture of petrochemicals is already of use to the refiner in his production of fuels and lubricants.

The choice between use of petroleum intermediates in petrochemical manufacture versus their use in finished petroleum products thus has some tantalizing aspects. In the case of petroleum refining processes one can predict investment and operating costs with a fair degree of certainty and there is sufficient knowledge of the potential market and marketing costs to determine profit and economic payout.

In the case of petrochemicals, investment and operating costs must be estimated with sufficient contingency to cover technological developments during the planning, design and con-

struction stages of the project. The market can only be predicted for a relatively short future period—and may vanish over night through changes in product formulation or appearance of substitute products.

Marketing cost forecasts are fraught with unknowns such as by-product disposal problems, making the profit aspects and a satisfactory return on investment in the project far from certain. However, the premium price enjoyed by petrochemicals over conventional refinery products makes certain ventures in the petrochemical field extremely attractive.

Tabulated in Table 1 are some of the elements of "The Market Concept" that affect engineering decisions in the design of refinery and petrochemical process plants.

**TABLE 1**
**Elements of "The Market Concept"**

| | Petroleum Refining | Petrochemical Manufacture |
|---|---|---|
| Process Technology | Established | Usually novel |
| Mechanical design Standards | Established | Often none Applicable |
| Safety Practices | Established | Determinable |
| Statistical Background of Production, Yield, Quality, etc. | Available | Often not Applicable |
| Market Trend Data | Available | Usually not Available |
| Competitive Product Data | Known | Sketchy |
| Marketing Territory | Known | Variable |
| Transportation Costs | Known or Calculable | Variable |
| Technological Obsolescence | Normal | Usually Fast |

As an example let us consider a refiner who has available 8.0 Mmcf per day of tail gas from a typical mid-continent catalytic reformer unit. This gas has an average composition of:

| | Volume Percent |
|---|---|
| $H_2S$ | 0.15 |
| $H_2$ | 83.85 |
| $CH_4$ | 8.00 |
| $C_2H_6$ | 4.00 |
| $C_3H_8$ | 2.00 |
| $C_4$ and heavier | 2.00 |
| | 100.00 |

This amount of hydrogen will yield about 100 tons per day of ammonia. The processing is simple—the acid gases are removed by ethanolamine scrubbing. The gas is dried and chilled before it enters a low-temperature gas separation and nitrogen wash unit. Additional pure nitrogen is added to bring the composition of the scrubbed gas to the stoichiometric ratio of $3H_2$:$1N_2$. It is then compressed to the pressure of the ammonia synthesis and enters the synthesis loop. The product is anhydrous liquid ammonia. Typical investment and operating costs are shown in Table 2.

**TABLE 2**
**Costs for a 100 Ton Per Day Ammonia Plant**

| OPERATION | Cost |
|---|---|
| Ethanolamine Scrubbing | $ 200,000 |
| Gas Dehydration and Refrigeration | 120,000 |
| Low-Temperature Separation | 1,000,000 |
| Synthesis Gas Compression | 780,000 |
| Ammonia Synthesis | 900,000 |
| Ammonia Storage and Loading Facilities | 100,000 |
| | $3,100,000 |

If capitalization is available at 6 percent and it is desirable to amortize the investment in ten years the annual depreciation charge must be 7.60 percent. However, few refiners wish to use an amortization period that long considering the risk involved. Most would prefer to retire the debt in five years which raises the depreciation charge to 17.76 percent. The return on investment may be assumed to be 6 percent and real estate taxes, insurance, vacations, social security, and other fixed costs will amount to another 2.5 percent. Thus, for a ten-year payout period we have fixed charges of 7.60 plus 6.00 plus 2.50, or 16.10 percent based on investment, or $500,000 annually.

On the basis that the combustible materials other than hydrogen are recovered as fuel, hydrogen consumed in the process can be charged on a Btu basis. With 1050 Btu gas at 14 cents per Mscf, fixed gas costs .14/1.05 = $.1333/MM Btu. Daily hydrogen consumption; .8385 × 8.00 = 6.70 Mmscf

6.70 × 324 = 2150 MM Btu
worth .1333 × 2150 = $290 per day
or $87,000 per year

Operating labor is estimated to be seven men per shift.

At $2.00 per hour
7 × 204 × 2.00 = $336/day
Supervision at 40% of labor = 134
$470/day
$470 × 365 = $170,000 per year

Maintenance labor and supplies may be estimated at 6 percent of the investment. This is equivalent to $186,000 annually.

Utilities may be estimated as:

| | |
|---|---|
| Electricity @ $.007/KW | $680/day |
| Steam @ $.30/M lbs. | 17 |
| Cooling water @ $.015/M gals. | 60 |
| | $757/day |

Chemical consumption is estimated to amount to $865 per day for caustic soda and ethanolamine. The cost of ammonia synthesis catalyst based on a two-year life is $3000 per year.

The sum of these utilities and chemicals represents an annual expenditure of $487,000 based upon a 300-day year. This brings the total annual cost to $1,430,000. At $72.00 per ton selling price at the works, the sales revenue will be $2,160,000 per year, giving a profit of $730,000, before taxes. The return on investment then allows a payout period, before taxes, of 4.25 years.

The average refiner has several competitive potential uses for his hydrogen. For instance, it can be used to catalytically desulfurize and improve stability and gum-forming tendencies of thermally cracked naphtha, to hydrodesulfurize cat-reforming charge stocks, to upgrade refractory recycle stocks to allow their inclusion in distillate fuels, and to desulfurize cat cracking charge stocks.

As one example, consider a unit designed to process 12,000 barrels per stream day of fluid catalytic cracking recycle stock to produce a low-cetane diesel fuel capable of blending with straight-run gas oils to yield a diesel fuel meeting average specifications. Such a unit is estimated to cost $2,-800,000. Considering payout period, operating supplies, labor, and utilities as before, we get the costs shown in Table 3.

**TABLE 3**
**Operating Costs of a 12,000 B/D Hydrodesulfurizer**

| | | |
|---|---|---|
| Investment @ 16.10 Percent | | $450,000/year |
| Hydrogen Consumption 2.36 MMSCFD @ $.1333/MMBtu | | $ 33,700/year |
| Operating Labor 1 man/shift, Plus Supervision | | $ 24,500 |
| Utilities | | |
| Electricity @ $.007/KW | $135/day | |
| Steam @ $.30/M lbs. | 88 | |
| Water @ $.015/M Gals. | $ 42/day | |
| Gas @ $.14/MCF | 215 | |
| | $480/day = | $158,000 |
| Maintenance @ 6 Percent of Investment | | 168,000 |
| Catalyst Based on 2-Year Life | | 32,000 |
| | | $866,200 |

FCC cycle stock is normally used as cutter stock to produce #6 fuel oil. If used in 50-50 mix with residual tar worth $0.84 per barrel, based on $0.1333 per MMBtu, to produce #6 fuel oil worth $2.10 per barrel, it would have a value of $3.358 per barrel. If, by hydrotreating, a diesel fuel worth 8.875 cents per gallon is produced, the value of the cycle stock has appreciated $0.37 per barrel, or $4434 per stream day and $1,463,000 per year. This yields a profit of $600,-000 per year. Under these conditions payout time will be 4.7 years.

In this operation, 2.36 of the 6.92 MMscf per day of hydrogen available

from the cat-reforming operation is consumed. The remainder may be used in upgrading other stocks in the refinery. The value of such upgrading can be evaluated in similar manner. Various combinations are possible and the hydrogenation operations showing promise selected for further engineering study, and the others rejected.

The actual value of hydrogenation to any refinery would depend on the market for the various products. Thus, the decision whether to produce ammonia or other petrochemical, or whether to upgrade petroleum stocks, is based upon market analysis.

The engineer, to function properly in the complex technology of today, must therefore broaden the scope of his thinking to include marketing and economic considerations, as well as purely technical matters. The extent of such increased scope, and its significance in engineering practice will, of course, vary depending on the position of the engineer in the company's organization, and the position of the company in the industry.

However, to a greater or lesser extent, each engineer will benefit himself and his company by familiarizing himself with the market significance of his work and by considering or developing market and economic background information as a guide for his technical work, be it the design of a simple modification to a gasoline stabilizer, or project engineering of a complete petrochemical manufacturing facility.

Backing up purely technical skills with an engineering philosophy oriented to the "Market Concept" will result in engineering of plants and processes that provide:

- Flexibility in operating capacity;
- Adaptability to changes in charge and product specifications
- Convertibility to different operations in the future.

The practical application of the "Market Concept" to engineering practice requires information and tools not formerly utilized in technical work. The information, in the form of statistical data and trends regarding market volume, prices, and costs, must be combined with technical information on capacity, yield, quality, operating cost and investment cost to develop economic background for design.

The handling of the large volume of calculations required by such a combination cannot be effected in reasonable time or at economical cost by an individual or group engineering effort using conventional computing means. The "trial-and-error" and "multiple-choice" types of calculations characteristic of such statistical work can only be handled economically by electronic computers. Such machines, originally developed for handling clerical and accounting functions, are of inestimable value to engineers in solution of complex technical problems.

More significant to the "Market Concept" in engineering, these electronic computers are ideally suited for combining statistical data on markets, price and other economic elements with technical information on capacity, yield and other technical factors to develop economics of different capacities, products, yields, market volumes, effect of competitive conditions and the many situations which must be considered when the "Market Concept" is introduced into refining and petrochemical engineering.

Many engineering and economic calculations have been reduced to machine programs. By means of these programs payout calculations for varying process operating cost factors—which would take an engineer about six hours by conventional computation methods—can be setup, calculated, and printed in about 15 minutes, using clerical help.

The extension of engineering work to include the "Market Concept" is a logical result of the entrance of our highly technological civilization into a period of dynamic industrial growth. The problems brought about by the complex interweaving of technical and economic considerations must be resolved by engineers as part of their professional responsibility, otherwise unnecessary and costly mistakes will be made which will affect the economic well-being not only of isolated companies, but of whole communities and industries.

The "Market Concept" in engineering of refineries and petrochemical plants is thus one aspect of the engineer's growing importance in industrial management. With adequate technical training, a philosophy oriented toward economic significance, the availability and use of market and economic information, the application of electronic computing machines, and the proper utilization of engineering service companies in the development and planning stages, the engineer can operate at the management level in the selection and design of process plants and equipment, for petroleum refining or petrochemical manufacture. ##

### Meet the Authors

Parker

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F. D. PARKER received his B.S. degree in chemical engineering from the University of Michigan in 1936, then got his M.S. degree in 1937. After graduation, he spent 14 years with Union Oil Company of California, then joined Bechtel Corporation as chief process engineer. From 1945 to 1955, Parker was a consulting engineer in Los Angeles, chief process engineer for Badger process division, Stone and Webster Engineering Company and manager of the Western headquarters for Blaw-Knox Company. Parker is now vice president, Engineering Petroleum division of Arthur G. McKee & Company, Cleveland.

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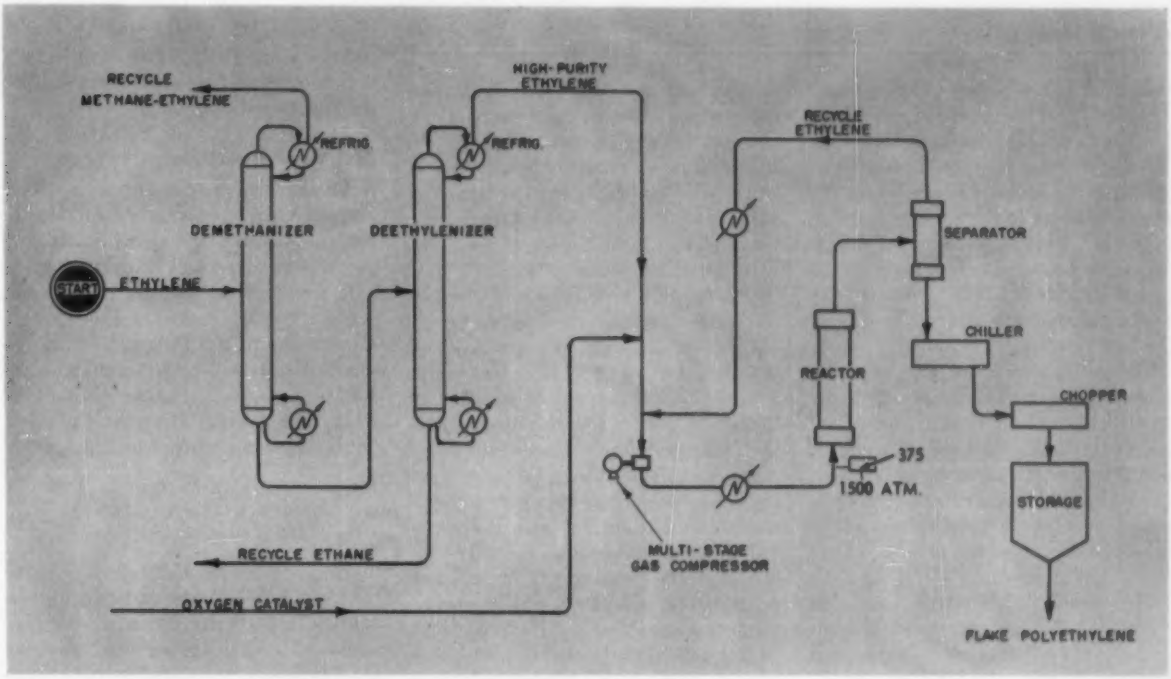


FIGURE 1—Schematic flow diagram for the manufacture of polyethylene by the (ICI) high pressure process.

# Which Polyethylene Process?

Petrochemicals 36

**Here is a comparison of the three low and one high pressure polyethylene processes that are commercially available.**

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POLYETHYLENE IS the glamor plastic of this decade. First there was one and then three and now more than eight different processes for the manufacture of this newest of the plastics. Everywhere one turns, the familiar squeeze bottle is standing ready for the touch. This, however, is a minor use in comparison to the amount used for films and sheets.

The basic raw material for polyethylene manufacture is ethylene which is available from refinery offgas and from the thermal cracking of ethane and propane. The economical production of ethylene usually requires a larger quantity than can be used for a single product. This tends to give the advantage in polyethylene production to companies making other products using ethylene as a starting material, although along the Gulf Coast pipe line ethylene is available.[1] An ethylene pipe line is currently being discussed for the Whiting, Ind., region.

Since ethylene is the most stable of the olefins, it is the most difficult to polymerize. All commercial processes for the production of polyethylene use catalysts to reduce the required energy of activation. At the present time, five such processes are being operated, constructed or studied. The details of some of these processes will be discussed.

## ICI Polyethylene Process

The ICI process was developed by Imperial Chemical Industries, Ltd., and is the major process now used for commercial production of polyethylene. Because this process uses very high reactor pressures, it has become known as the "high pressure" process.

In the ICI process, the usual ethylene plant product must be purified before it can be used for polyethylene manufacture. Minimum specifications call for ethylene of 99.0-99.9 percent purity. After purification, the ethylene is polymerized by either the bulk polymerization process or by the solvent polymerization process.

**Bulk Polymerization**—The purified ethylene is mixed with about 600 ppm of oxygen and compressed to 1500 atmospheres pressure. The oxygen serves as a catalyst but is con-

sumed in the reaction. The mixture is heated to 375 F. and fed to a stainless steel tubular reactor. Once initiated the reaction proceeds quite rapidly with about 25 percent of the ethylene being converted to high molecular weight polymer. The gas is reacted isothermally and special means are provided to maintain essentially isothermal conditions of 375 F.

The effluent from the reactor passes to a separator in which the unconverted ethylene is removed and recycled to an intermediate stage of the charge gas compressor. This ethylene contains no oxygen which, though serving as catalyst or initiator, is consumed in the reaction. (See Figure 1.)

The liquid polyethylene from the separator is water-white and of high viscosity. It is chilled quickly, and solidifies in the vicinity of 230 F. Final stages in the process are chopping, bin storage, sacking and shipping.

**Solvent Polymerization**—In the solvent polymerization process, an operating pressure of about 1000 atmospheres is used. An aromatic hydrocarbon is added as a solvent to improve polymer solubility in the reaction zone and thus permit easier and quicker removal of the polymer formed before it is attacked by growing polymer chains which can result in cross-linking. A mixture of fresh and recycle ethylene, plus about 20 ppm oxygen catalyst, is dissolved in a benzene-water mixture at 375 F. The major constituents in the charge have a weight ratio of about 1.0:1.0:1.5 ethylene:benzene:water. The water contains 100 ppm of oxygen.

The charge is fed to a stainless steel tubular reactor and during the course of reaction additional water is injected to maintain a more constant catalyst concentration throughout the reactor. About 17 percent of the ethylene is converted to polymer. Isothermal conditions of 375 F. are maintained. The effluent from the reactor passes to a separator where the unconverted ethylene is removed and recycled as in the bulk process. The liquid, consisting of polymer, benzene and water is sent to a distillation unit where benzene and water are ultimately separated from the heavier polymer.

Another **Solvent Polymerization** process is known as the water-solvent process. In this process, water carrying additional initiator is injected at multiple points along the reaction tube in order to attain a higher conversion of the ethylene per pass through the reactor. The "half life" of these initiators normally used is low and consequently it is necessary to continually add initiator to hold up the rate of polymer formation. The separated polymer is handled as described above for the Bulk Polymerized ethylene. These solvent processes are said to give a polymer having lower dielectric strength and optical clarity than the bulk polymer.[1]

Imperial Chemical recently announced the production of a high density polyethylene which can be produced in standard high pressure equipment. This polyethylene has greater rigidity, and can resist boiling water temperatures for long periods. The resin sells for 56 cents per pound, compared to 41 cents for the standard resin.[2] One of the licensees is already producing the newer polymer commercially.

It is claimed that the high pressure bulk polymerization process still produces a superior resin for applications where dielectric strength is the determining factor. The simplicity of the operation compared to the elaborate solvent recovery process so often associated with the low-pressure process is much to the advantage of the ICI process. Now that the standard high pressure methods have been modified to control chain branching and produce a polymer with better heat resisting properties the competition of low pressure processes is somewhat alleviated.

Any process which has been successfully operated for a number of years by several different companies has a decided advantage over any newer and untried process. Techniques developed over long periods of operation are not to be discounted without considerable thought. Higher initial costs (if any) may be easily overlooked in favor of more knowledge about the operation variables.

It is generally assumed that any processing step adds to the value of the product at least three fold. It also adds to the cost of production. The many added recovery and clean-up steps required in the low pressure processes may well be the cost differential which will give the high pressure process the edge.

### Ziegler Polyethylene Process

The Ziegler process of polyethylene manufacture is currently being studied and piloted by several companies in the US (Hercules, Koppers, Carbide, Du Pont, Monsanto, Dow). This process had its start in 1940, when Ziegler found that lithium ethyl polymerized ethylene to a waxlike solid. Aluminum triethyl was found to work even better. The ethylene adds to the aluminum alkyl as follows[3]:

$$(C_2H_5)_2Al + C_2H_4 \rightarrow$$
$$C_2H_5CH_2 \cdot CH_2 \cdot Al(C_2H_5)_2 \rightarrow$$
$$C_2H_5(CH_2 \cdot CH_2)_nAl(C_2H_5)_2$$

During the course of Ziegler's experiments, a careless student left traces of colloidal nickel in the reactor. The traces of nickel caused the ethylene to polymerize to pure butalene and gave a large increase in the reaction rate.[4] Colloidal nickel and aluminum alkyl was originally used as a catalyst. Cobalt and platinum, and latter zirconium and titanium, were found to possess catalytic activity, and finally a series of combinations of other metallic catalysts were prepared. All of these catalysts were prepared by decomposing aluminum triethyl with the metallic chloride in a Grignard reaction.[5] The catalyst used at present is a mixture of aluminum triethyl and titanium tetrachloride. The catalysts are suspended in a carefully dried aliphatic oil.

This dual catalyst serves to direct the polymerization. The metal alkyl such as aluminum triethyl, promotes the polymerization of ethylene. The secondary-, or co-catalyst, which may be the finely divided metal or a metal derivative, serves to control the degree of polymerization. Aluminum alkyls are spontaneously inflammable and normally require very careful handling. In this process, the catalyst is carried in a hydrocarbon solvent under conditions that make it safe to handle in the reaction step. Only a trace of catalyst is required, so a very dilute solution is employed.

Aluminum alkyls a few months ago were laboratory curiosities available from specialty manufacturers at $5-$10 per gram. Ziegler has found a new method of preparing the aluminum alkyls and his licensee, Hercules,

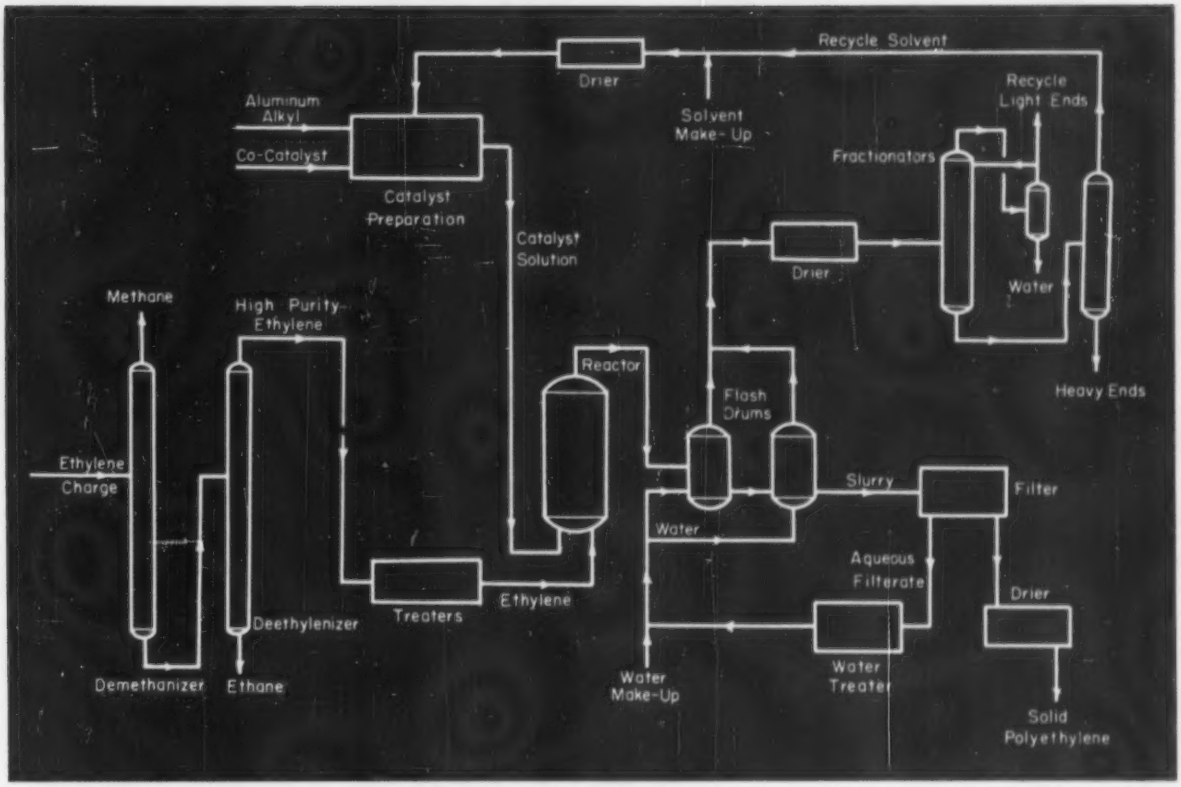


**FIGURE 2—This is the Ziegler low pressure process for making polyethylene. Notice the catalyst preparation section and the ethylene purification equipment.**

is offering aluminum triisobutyl at $25 per pound.[5] This is still too high and the price will come down soon to $1-$2 per pound. Captive production by the polymer producers may be nearer to the $1 cost now with most of the kinks worked out of the catalyst manufacturing process. Ziegler states that the catalyst should come down to a cost of 21-32 cents per pound soon.[5]

The ethylene used in the Ziegler process must be free of water, oxygen and carbon dioxide. The ethylene feedstock must also be sulfur-free. The purity of the ethylene required for the Ziegler process is not surely known. Some literature references cite the use of dilute ethylene as an advantage of the Ziegler process,[2] and other references in the literature state that 99.0 plus percent purity ethylene is used.

**Ziegler Polymerization**—The reaction can be carried out by passing ethylene into a suspension of the catalyst in a petroleum fraction, e.g., diesel oil.[3] The temperature is maintained below 160 F, and the polyethylene is formed as a flocculent mass which is washed almost free from the catalyst with alcohol.

Although the process can be carried out at atmospheric pressure, a moderate pressure of about 200 psig is probably more efficient and economical. Raising the temperature of the reaction results in chain breakage, and in extreme cases butylene is formed; this occurs at 212 F and about 1055 psig.[3]

The purified ethylene gas is charged to the reactor. The catalyst, dissolved in a carefully dried paraffinic solvent, such as a $C_6$ or $C_7$ fraction, is charged to the reactor as a very dilute catalyst solution. The reactor is maintained at a pressure in the range of one atmosphere to 100 psig, and a temperature of 140-170 F.

The reactor product is sent to a series of flashed drums to remove the solvent and precipitate the polymer. These drums are maintained at conditions in the range of 3 to 5 psig and 150 to 160 F. Water is added to the flash drums to destroy the residual catalyst and remove the polyethylene as a slurry. The solvent is sent to a dryer to remove entrained water and is then charged to a fractionator where water and light ends are removed as an azeotrope. The bottoms are sent to a second fractionator where recycle solvent is taken overhead and heavy ends are discharged as the bottoms. (See Figure 2.)

The water-polyethylene slurry is sent to a filter or continuous centrifuge. The aqueous filtrate is treated and recycled to the flash drums. The solid polyethylene product is dried and sent to such finishing steps as shredding or extrusion. This product has greater rigidity and heat resistance than conventional (ICI) polyethylene; however, it has poorer electrical resistance because of traces of residual catalyst. The capital investment is relatively low, so it is a very attractive process for polyethylene manufacture. The overall yield of polymer is in the range of 95-98 percent of the ethylene consumed.

Polymers prdouced range in molecular weight from 10,000 to 3 million compared with 10,000 to 50,000 for

the high pressure polymerization (ICI) process. The polyethylene produced can be fabricated at a relatively high temperature, 340 F. The yield strength of the polymer is in excess of 35,000 psi and this is attributed to the smaller number of branched chains in the polymer. This lack of branching has been shown by infra-red analysis.

The advantages of this process are that it can be carried out at atmospheric pressure (although a moderate pressure up to about 200 psig would probably be more economical and efficient), and that the product has a higher melting point and molecular weight as well as greater strength than the conventional high-pressure (ICI) polymer.

The disadvantages are that working in solvents presents the problem (and cost) of solvent recovery, the necessity for removing minute traces of inorganic catalyst, and the more difficult fabricating techniques required by the more rigid polymers. However, the licensees seem assured that they will benefit economically, even after payment of large license fees and royalties, once these disadvantages are brought into balance.

### Phillips Polyethylene Process

The Phillips process for the manufacture of polyethylene requires ethylene of the same specifications as the Ziegler process. While low purity ethylene may be charged to the reactor, it is desirable from the process standpoint to minimize the nonethylene constituents. Oxygen, water and carbon dioxide are harmful to the catalyst, so they are removed by passing the high purity ethylene through appropriate treaters, such as hot metallic copper for oxygen, anhydrous calcium sulfate for water, and supported caustic for carbon dioxide.

The treated ethylene is charged to an absorber where it is dissolved in xylene at a pressure of 500 psi and a temperature of about 60 to 90 F. The solution from the absorbers contains 5 to 7 weight percent ethylene. The solution is brought to the desired temperature (about 300 F) and pressure and sent to the reactor where it contacts a catalyst.

Phillips uses, if the limited patent literature is any guide, a completely inorganic catalyst. The catalyst is principally hexavalent chromium oxides on an alumina-silica carrier.[5] The patent literature may not give the whole story and there may be other oxides along with the chromium oxide.

The reactor contains a stirred section to provide intimate contact of the ethylene with the catalyst. A high solvent-to-catalyst weight ratio is desired to provide a high yield of polymer. The solvent serves several functions in addition to its role as a carrier for the ethylene. It protects the growing polymer chain from chain-breakers, controls the viscosity of the solution, dissolves much of the solid polymer from the catalyst to help maintain good catalyst activity, controls the rate of ethylene consumption to promote good polymer growth, and it also serves as a medium for the dissipation of the heat of reaction. If a solvent is not used under these reactor conditions, a polymer mixture is obtained which contains molecules as low as butane.

Additional catalyst is added to the reactor to compensate for that which is carried out with the reactor product. The product stream goes to a separator where the pressure is reduced to approximately 100 psi and the temperature is around 300 to 400 F. The unreacted gas is returned to an absorber, and the hot solution is sent to a filter for removal of the entrained catalyst. The catalyst is sent to a deresining chamber where additional polyethylene is recovered from the catalyst. The hot solution is combined with the separator effluent while the catalyst is sent to a regenerator.

The hot filtrate is sent to a chiller where its temperature is reduced to 70 to 150 F. This temperature reduction causes the high molecular weight polymer to separate as a solid and form a slurry with the solvent. Antisolvents, such as propane, butane or alcohols may be added to facilitate precipitation of the polymer from the solution. The slurry is charged to the cold filter. If a xylene fraction is used as the solvent, the filtrate is sent to a second fractionator which separates between alkylated xylenes and the small amount of lower molecular weight polymers formed in the process. A side reaction occurs between the solvent and the ethylene in the presence of the catalyst to yield a small amount of alkylate which may be removed from the process or recycled as solvent. (See Figure 3.)

The solid polymer is discharged from the cold filter and sent to a final solvent recovery section, from which it may be sent to such final finishing steps as shredding or extrusion.

Phillips polyethylene appears to be somewhat similar to Ziegler material although it is made by a different process. It is of high molecular weight, high melting point and high strength and has about the same disadvantages.

An advantage of the Phillips process is the almost complete conversion of the ethylene to polymer. This is an important advantage because the purification of ethylene constitutes a major expense in any polyethylene process.

The resin formed by the Phillips process is of high molecular weight. The resin has a higher melting point and is somewhat more rigid than the conventional or high-pressure types. Products fabricated from this polymer are said to withstand boiling water temperatures without distortion. Dielectric properties are suspected to be somewhat lower than the high-pressure polyethylene because of the presence of minute particles of catalyst.

Disadvantages of the process could be the added unit operations that are necessarily associated with the recovery and purification of the polymer. These added steps require capital investment and add to the production costs of the polymer.

### Standard Oil Company Indiana Polyethylene Process

The Standard of Indiana process for the manufacture of polyethylene[10] requires ethylene of high purity. Twenty-five ppm of oxygen or less is normally permitted.

**Catalyst**—Nickel-charcoal catalyst containing about 5 percent nickel is used. The nickel is deposited on the charcoal as a salt and then converted to oxide by heating to 500 F. Before actual use in polymerization the catalyst must be activated by reduction with hydrogen at 392-500 F.

Molybdena-alumina catalyst with about 8 percent molybdena is also used. The molybdena-alumina catalyst is calcined at 934-1114 F and

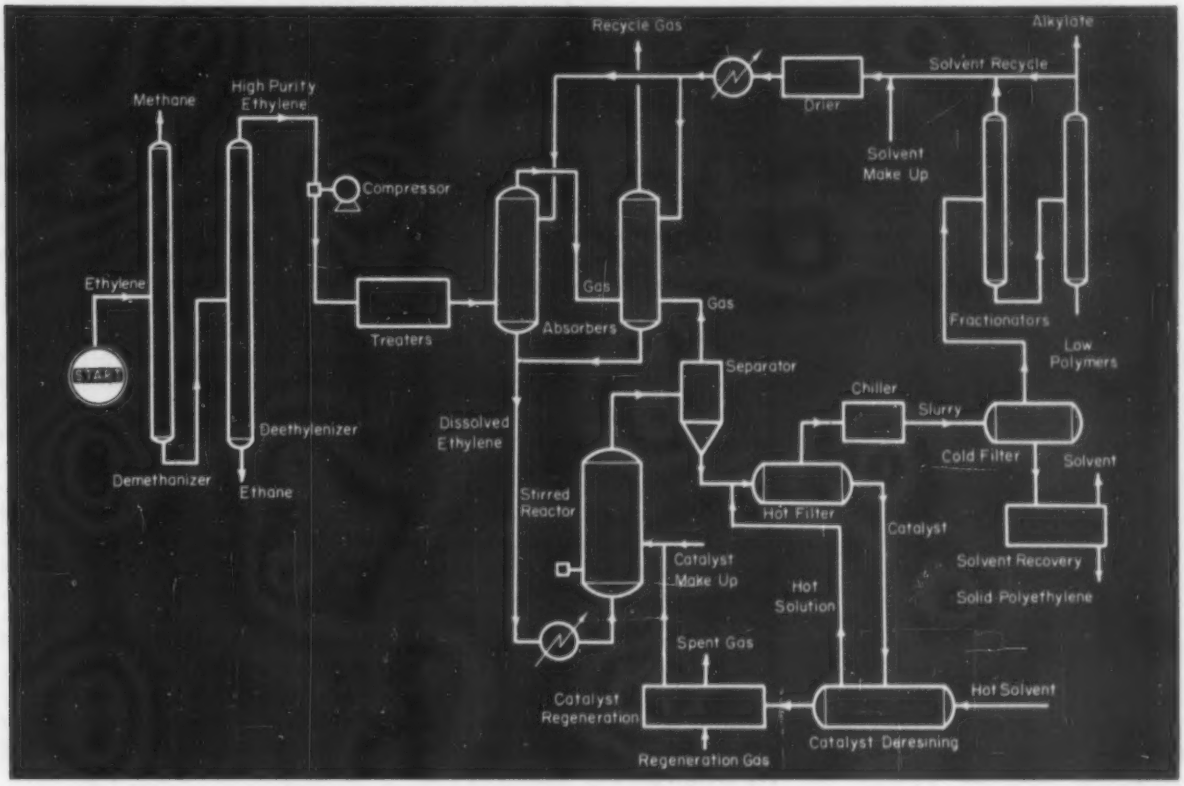


**FIGURE 3—This is our interpretation of the Phillips low pressure polyethylene process. Notice the equipment for catalyst and polymer recovery.**

used as a 6-14 mesh granular material or as a powder. It must be activated by hydrogen before use and this is accomplished by soaking at 807-898 F in a hydrogen atmosphere.

**Polymerization**—Ethylene, containing 25 ppm oxygen is dissolved in a solvent (xylene) and pressured to 1000 psi for introduction into the tubular reactor. The reactor is packed with catalyst and cooled from activation temperature to the polymerization temperature of less than 300 F. The polymerization pressure is not critical and the only function is to maintain the solubility of ethylene in the xylene. The temperature is as low as possible, in the neighborhood of 392 F. in order to make as much solid polymer as possible.

The polymer is recovered from the solvent in a series of separator drums operating at atmospheric pressure. The polymer is essentially free from catalyst.

**Operating variables**—The most critical process variable is the temperature. Lower polymerization temperatures produce higher yields of solid polymer and less oils and waxes. Thus temperature is the most influential of the process variables.

The pressure is not critical. Only sufficient pressure is maintained to insure solubility of the ethylene in the solvent (xylene) at the temperature of the reactor.

The solvent has many functions in the polymerization process. One function is to remove the polymer as formed and thus keep up the catalyst activity. Another is to help control the polymerization temperature and thus has a direct influence on the pressure requirements of the reaction.

Oxygen is a catalyst poison and 25 ppm is the maximum tolerated. Acetylene can be tolerated by the catalyst. When the conversion rate falls below 25 percent the catalyst should be reactivated. The catalyst can be reactivated by heating under relatively mild pressure in the presence of hydrogen. The catalyst activity is fully restored.

After long periods of use the catalist may become filled with coke-like materials and lose its ability to form polymer at the desired rate. This can be alleviated by burning these materials off the catalyst using air at mild temperatures.

**Polymer Characteristics**—A highly crystalline polymer with a density of 0.95 is made by using the nickel-charcoal catalyst. Molybdena-alumina catalyst produces a polymer having a range of densities of 0.94 to 0.98. The nickel-charcoal polymers are softer and more flexible than those produced by the molybdena-alumina catalyst.

High crystallinity is another characteristic of these polymers. About 80 percent crystallinity is obtained with the nickel-charcoal catalyst and 76-95 percent by the molybdena-alumina catalyst. Because of this high crystallinity these polymers exhibit higher yield strengths than the high-pressure polyethylenes. Molybdena-alumina polymer having a density of 0.96 and about 80 percent crystallinity has a yield strength of 4000 psi compared to 1000 psi for conventional high-pressure polymers. Melting points are also higher, being about 266 F for the molybdena-alumina polymer.

## Which Polyethylene Process?

The Standard of Indiana low pressure process seems to have the fewest disadvantages of all the low pressure polyethylene processes. The solid, completely inorganic, catalyst should present less problems than any of the other low-pressure processes except perhaps the Phillips process. The ease of separation of the polymer from the catalyst and the solvent are also advantages for this process. The freedom from catalyst poisons and the few influencing process variables should help toward the acceptance of this process.

One disadvantage is the mixed polymer that is obtained from the polymerization. In this case any particular molecular weight polymer must be separated from the reaction product. Also, the use of a solid catalyst will always present a problem because of the difficulty of removing minute traces of the material from the product polymer.

This disadvantage will probably be solved when commercial production is started using this process. The polymers formed have very good physical properties and while they cannot compete for all uses of polyethylene they will surely serve in many specific needs.

### Interprocess Competition of the Polyethylene Processes

The production of polyethylene has shown a steady growth since commercial production was started. The 1954 production was 210 million pounds; by 1955 the production was 402 million pounds; and the 1956 production is estimated to reach 550 million pounds. The estimated production figures do not include the low-pressure installations expected to begin production late in 1956 and early in 1957.

The fact that production capacity is to exceed sales potential in 1956 makes it important to evaluate the effect of interprocess competition between high-pressure and low-pressure resins. The primary consideration when supply exceeds demand is normally the price of the competing products. Competition and increased volume of production have caused the price reductions which have taken place from time to time on polyethylene resin.

At first glance it would appear that low-pressure processes would offer much lower costs of manufacture, since the original investment would be much lower than for a high-pressure plant. The lower initial investment will undoubtedly make the low-pressure processes attractive for some producers. A true picture of the relative costs of production, however, is complicated by a number of variables. Many of these variables can be evaluated only by making assumptions based on rather sparse data.

One of the closely guarded secrets surrounding all methods of polymerization is the polymerization rate. Patents issued to Standard Oil Company of Indiana[6,7] seem to indicate that reaction rates for low-pressure processes may be rather slow. It is known that reaction rates for low-pressure processes are fast enough to insure a profit at the present prices, but it is difficult to estimate the minimum profitable price for the resin. It is equally difficult to estimate the minimum profitable price for a high-pressure resin.

A major consideration in interprocess competition evaluation is the fact that a number of high-pressure installations are presently in operation, and have probably repaid the original investment out of their earnings. To be considered a good risk, a plant should pay out in not more than 1.6 years.[8] However, most new polyethylene plants would be expected to require slightly longer payout periods. The main difficulties in high-pressure operations, handling of the pressures involved, have apparently been solved by the evolution of high-pressure techniques. For a time, at least, low-pressure operations may encounter difficulties not now foreseen.

Another complicating factor in evaluating interprocess competition is the difference in the characteristics of the high-pressure and low-pressure resins. It is fairly well established that the low-pressure resins have greater rigidity and can withstand higher temperatures than can the high-pressure resins.[9] Low-pressure resins seem more susceptible to cracking. The high-pressure resins have greater flexibility, better dielectric properties, and better optical qualities. Some persons believe the two resins to be so different that little or no interprocess competition will occur.

A final complicating factor is the variable cost of the ethylene used as a raw material. The cost of this starting material ranges from three to six and one-half cents per pound. The cost of this commodity at individual plants may be the decisive factor in some competitive pricing.

In spite of the differences which exist in the high-pressure and low-pressure polyethylene resins, there seem to be wide areas where polyethylene produced by either process could be used. It seems almost certain that increased production and interprocess competition will result in lower prices for the finished resin. These price adjustments are likely to be small reductions in price and to reflect savings in cost of manufacture rather than abnormally small profit margins. As prices decrease, the resins will be put to new uses, however, some smaller companies will be hard put to meet competition. Both the high and low-pressure processes will be around for some time to come. The polyethylene industry is moving fast and in time (it could be sooner than you think) a full range of polyethylene products (ranging in densities from 0.92 to 0.98) and physical properties will become available from each of the commercial processes using essentially different processing techniques.

In addition to the processes discussed here, there are several others in the offing, e.g., Du Pont, Aries and others. The Aries organization is active in the field of olefin polymerization, including the alpha-olefins (ethylene and propylene) and of dienes in co-polymerization to produce rubbers. Surely the polyethylene situation is complicated, not only by the availability of different processes, but also by the availability of new products such as polypropylene.

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# Here Are Complete OXO Reaction Data

**This is a new type of catalysis for the petroleum industry. Discussed here is everything from commercial charge stocks to kinetics and mechanisms of the reaction.**

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THE OXO reaction has introduced a new type of catalysis to the petroleum industry. The manner in which a molecularly dispersed metal carbonyl transfers hydrogen and carbon monoxide to an olefin will be discussed. An understanding of the mechanism of the oxo reaction may lead to better process control and new applications.

The reaction of olefins with carbon monoxide and hydrogen in the presence of a cobalt catalyst to yield aldehydes is known as the *oxo* or *hydroformylation* reaction. In most cases, the aldehydes are hydrogenated in a separate step to give primary alcohols:

$$RCH=CH_2 + H_2 + CO \xrightarrow{Co} \begin{cases} \xrightarrow{H_2} RCH_2CH_2CH_2OH \\ \xrightarrow{H_2} RCH(CH_3)CH_2OH \end{cases}$$

It is convenient to refer to "oxo" or "hydroformylation conditions" to denote the conditions of temperature, pressure, and catalyst required for the oxo and related reactions. These conditions are approximately 75-200 C, 100-300 atmospheres of synthesis gas ($H_2$ and CO) and a cobalt catalyst, either freshly reduced metallic cobalt or a cobalt salt. The carbonyls of cobalt, dicobalt octacarbonyl, cobalt hydrocarbonyl, and tricobalt dodecacarbonyl may all be present under these conditions.

**Commercial Charge Stocks**—The starting materials for the oxo synthesis, as operated in the U. S., are propylene, copolymers of propylene and butylene, and butylenes. The largest manufacturing capacity is devoted to the production of "isooctyl" alcohols from mixed heptylenes, which in turn are produced from the co-polymerization of propylene with butylenes.

The "isooctyl alcohol" produced is a mixture of at least ten different C-8 primary alcohols, among which are 3,5-dimethylhexanol, 3,4-dimethylhexanol, 4,5-dimethylhexanol, 3-, 4-, and 5-methylheptanol; the dimethylhexanols are the principal components. Isooctyl alcohol is produced principally for its conversion to isooctyl phthalate, a valuable plasticizer in polyvinyl chloride formulations. This is an example of the familiar pattern of American chemical manufacture: chemicals to make more chemicals.

Propylene is the feed material in one large oxo plant which produces n- and isobutyraldehyde. This is one of the few operations in which the aldehyde is isolated and purified; usually the aldehyde mixture is reduced immediately to the corresponding mixture of alcohols. Isolation of the aldehydes is particularly feasible when they are low-boiling.

In another large oxo plant, butylenes are the feed material and amyl alcohols are the product. These amyl alcohols are all primary alcohols and thus differ from the C-5 alcohols isolated from fermentation processes. Other oxo syntheses are based on the use of propylene trimer and propylene tetramer to produce decyl and tridecyl primary alcohols.

Suggested uses for these materials and their conversion to other useful chemicals are contained in advertising material available from the five large commercial manufacturers (Standard of New Jersey, Standard of Indiana, Tennessee Eastman, Carbide and Carbon Chemicals, and Gulf Oil Corporation) engaged in oxo preparation.

In a typical operation, a mixture of heptylenes boiling at 76-99 C is mixed with recycle product and sufficient cobalt naphthenate (or other form of soluble cobalt) is added to give a concentration of 0.2 percent cobalt based on the total feed. The solution is pumped through a preheater and into a reactor where the liquid passes upward cocurrently with synthesis gas. The reactor may be an empty tube or it may be filled with an inert material such as Raschig rings. The temperature of the reactor is held at about 175 C and the pressure of synthesis gas ($1H_2:1CO$) is kept at about 200 atmospheres. The reaction is very exothermic; the conversion of ethylene to propionaldehyde is accompanied by the liberation of 34.8 kilocalories per mole. The

recycle product helps in removing the heat of reaction.

**Thermodynamics**—Thermodynamic data are available for the oxo reaction involving ethylene:

$$CH_2{=}CH_2 + CO + H_2 \rightarrow CH_3CH_2CHO$$
$$\Delta H = -34.8 \text{ kcal./mole}$$

Values for the free energy change and the equilibrium constant at several temperatures for the synthesis of propionaldehyde were obtained by Wenner and are listed in Table 1.

**TABLE 1**
**Free Energy and Equilibria Values for the Hydroformylation of Ethylene[1]**

| Temp. C. | $\Delta F$ (kcal./mole) | $K_P$ |
|---|---|---|
| 25 | —17.5 | $6.5 \times 10^{12}$ |
| 100 | —13.1 | $4.8 \times 10^{7}$ |
| 150 | —10.2 | $1.9 \times 10^{5}$ |
| 200 | — 7.3 | $2.4 \times 10^{3}$ |

These data show that the formation of propionaldehyde from ethylene and synthesis gas is very favorable at 1 atmosphere and moderate temperature. Although the oxo synthesis does not proceed at atmospheric pressure with a dicobalt octacarbonyl catalyst, measurable rates have been observed at as low as 10 atmospheres pressure and, indeed, the reaction has been shown to occur readily at room conditions when cobalt hydrocarbonyl is mixed with an olefin. It is of interest to note that the hydroformylation of an olefin usually occurs practically to the complete exclusion of its hydrogenation, even though the standard state free energy for the reaction:

$$CH_2 = CH_2 + H_2 \rightarrow CH_3CH_3$$

at 25 C. is —22.7 kcal./mole[2]. Hydrogenation becomes competitive only when the olefinic linkage is conjugated.

**Catalysts**—The first catalyst to be used in the oxo synthesis was the conventional Fischer-Tropsch cobalt catalyst containing cobalt:thoria magnesia:kieselguhr in the proportions 100:5:8:200. This was the standard Fischer-Tropsch catalyst used by Ruhrchemie in their synthetic fuel plants and was thus readily available in large quantity.

When in the reduced state, this catalyst is very active in the oxo synthesis, but the last three components, although they impart important properties to the catalyst for use in the Fischer-Tropsch synthesis, are superfluous for the oxo reaction. The Fischer-Tropsch synthesis is a heterogeneously catalyzed reaction and the condition of the surface of the catalyst, its method of preparation, and the manner in which it is activated, are of utmost importance. On the other hand, there is little doubt at the present time that the oxo synthesis is a homogeneous reaction in which the soluble cobalt carbonyls are the catalysts. When metallic cobalt is used in the oxo synthesis, its efficiency will depend, therefore, on the ease with which it is transformed to the carbonyl.

Although dicobalt octacarbonyl may be formed from an activated cobalt metal by using carbon monoxide, the conversion of cobalt salts to the carbonyl usually requires hydrogen. When an oxo reaction is carried out in the presence of cobalt salts, somewhat higher temperatures are required for a successful reaction than are necessary when the cobalt is added as the carbonyl. Thus, for example, the hydroformylation of 1-octene at 200-300 atmospheres of synthesis gas ($1H_2$:1CO) in a hydrocarbon solvent requires a temperature of 150-160 C. However, if the same concentration of cobalt is introduced as dicobalt octacarbonyl, the reaction goes very rapidly at 115-125 C. Obviously the *in situ* preparation of the carbonyl is responsible for the higher temperature requirement.

Practically any form of cobalt may be used as a catalyst for the oxo synthesis since under the usual conditions conversion to the dicobalt octacarbonyl occurs. This is also true of organic cobalt salts such as cobalt octoate or naphthenate both of which may be employed in the crude form in which they are offered, as accelerators for drying oils.

Although the contention that iron is an oxo catalyst frequently appears in print and many oxo patents claim iron as a catalyst, there is no clear-cut evidence to support such a contention. On the contrary, the best available evidence indicates that under the conditions in which cobalt functions as a catalyst, iron is inactive. In some of the early discussions on the nature of the catalysis, it was pointed out that cobalt and iron were oxo catalysts because these metals form hydrocarbonyls, whereas nickel did not form a hydrocarbonyl and hence was not a catalyst. However, a hydrocarbonyl of nickel, $[NiH(CO)_3]_2$, has recently been prepared.[3] At the present time it appears that the catalysis of the oxo reaction is limited to cobalt.

**Products**—When straight-chain olefins which contain the double bond in other than the terminal position are subjected to the oxo reaction, the products which result are almost identical with those obtained from the isomeric olefin in which the double bond is in the terminal position.

For example, the distribution of alcohols secured from 1-pentene and 2-pentene is about the same[4] : 50 to 55 percent of hexanol, 35 to 40 percent of 2-methylpentanol-1 and 10 percent of 2-ethylbutanol-1. As a general rule we may state that, starting with a straight-chain olefin, about 60 percent of normal and about 40 percent of $\alpha$—branched aldehyde or alcohol are obtained, no matter where the double bond is located.

When a branched olefin containing the double bond in other than the terminal position is submitted to the oxo reaction, the products which result are again almost identical with those secured from the isomeric olefin in which the double bond is in the terminal position.[4] Thus, essentially the same products result from 2-methyl-2-butene as from either 3-methyl-1-butene or 2-methyl-

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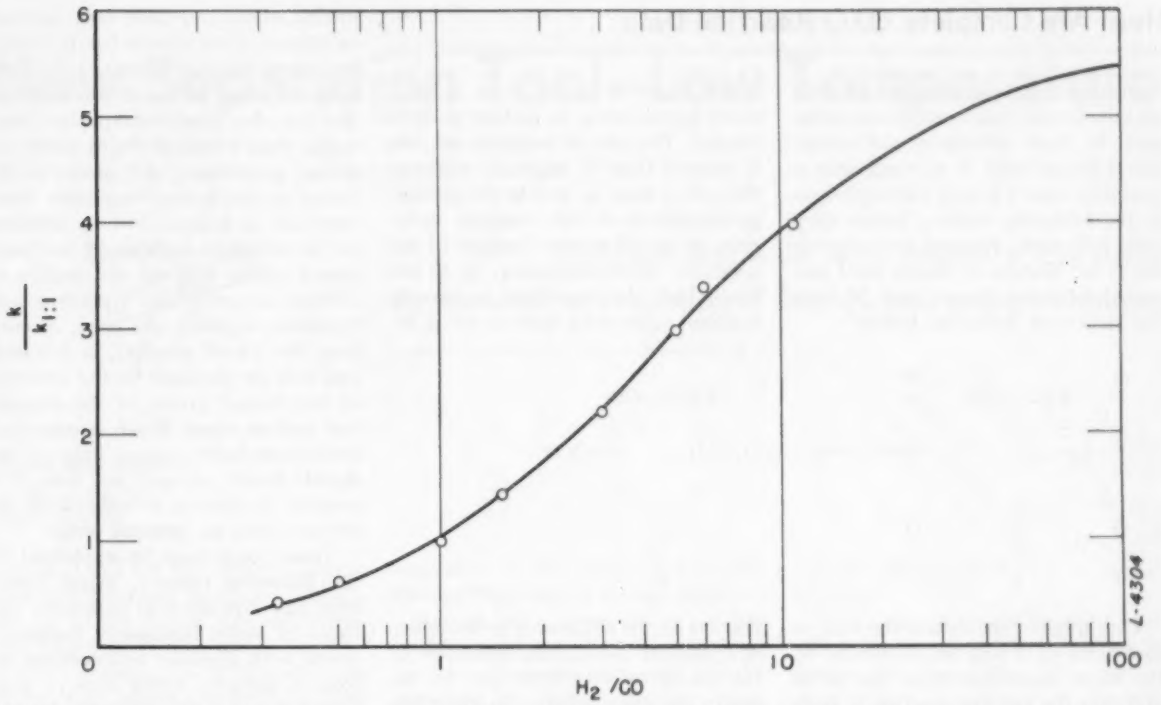



FIGURE 1—Comparison of specific reaction rate constants (k) for cyclohexene at an $H_2$:CO ratio at 110 C with the rate constant ($k_{1:1}$) at 1:1 $H_2$:CO versus the $H_2$:CO ratio. Curve calculated from Martin's equation,[9] Experimental points shown from unpublished work.[10]

1-butene: 55 percent of 4-methylpentanol-1, 45 percent of 3-methylpentanol-1 and 5 percent of 2,3-dimethylbutanol-1.

Isobutylene adds the formyl group predominantly to the terminal carbon atom; the chief product is isovaleraldehyde although about 4 percent of trimethylacetaldehyde is also obtained[5]:

$$CH_3-\underset{\displaystyle CH_2}{\overset{\displaystyle |}{C}}=CH_2 + CO + H_2 \rightarrow$$

$$CH_3CHCH_2CHO + (CH_3)_3C-CHO$$
$$\quad\;\; |$$
$$\quad CH_2$$

96 percent 4 percent

**Kinetics and Mechanism**—Natta and Ercoli[6] have studied the kinetics of the hydroformylation of cyclohexene using synthesis gas ($1H_2$:1CO) at total pressures ranging from 120 to 380 atmospheres; dicobalt octacarbonyl was used as the catalyst. The rate of hydroformylation was found to be first order with respect to the olefin and approximately proportional to the amount of cobalt present. Two groups of investigators[7,8] have reported that the rate of hydroformylation increases with increasing hydrogen pressure at constant carbon monoxide pressure and decreases with increasing carbon monoxide pressure at constant hydrogen pressure.

The fact that the rate varies inversely with carbon monoxide pressure has led to the postulation[7,8] that the first step involves the reaction of the olefin with dicobalt octacarbonyl to form an olefin-carbonyl complex, I, and carbon monoxide. Martin[9] showed that the following sequence of equations led to a kinetic expression which fits the data obtained with different ratios of gases at elevated pressures quite well:

$$RCH=CH_2 + Co_2(CO)_8 \xrightarrow{k_1} \underset{\text{I}}{Co_2(CO)_7 \cdot RCH=CH_2} + CO$$

$$Co_2(CO)_7 \cdot RCH=CH_2 + CO \xrightarrow{k_2} Co_2(CO)_8 + RCH=CH_2$$

$$Co_2(CO)_7 \cdot RCH=CH_2 + H_2 \xrightarrow{k_3} Co_2(CO)_8 + RCH_2CH_2CHO$$

$$Co_2(CO)_8 + 2CO \rightarrow Co_2(CO)_8$$

which gives

$$\text{initial rate} = \frac{k_1 k_3 P_{H_2}}{k_2 P_{CO} + k_3 P_{H_2}} [Co_2(CO)_8]\,[RCH=CH_2]$$

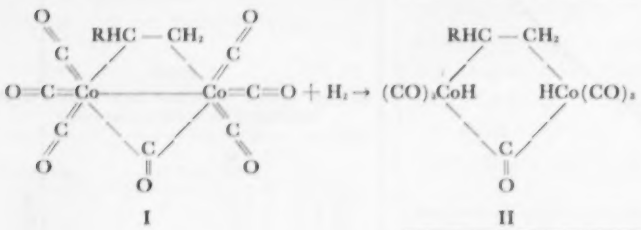
This sequence is similar to that originally suggested,[7] except that equilibrium is not maintained between dicobalt octacarbonyl and olefin on the one hand and complex, I, and carbon monoxide on the other.

The curve in Figure 1 has been calculated using this equation; the open circles are experimental points.[10] The curve shows that the maximum possible increase in rate over that at 1:1 $H_2$:CO in going to higher ratios of $H_2$/CO is about 6.

Although this mechanism appears essentially correct, there are cogent reasons for believing that I must react to form another complex, II, which then rearranges to give aldehyde and cobalt tricarbonyl. The complex or intermediate, I, is a large molecule and it is unlikely that it will homogeneously split a molecule of

'56 Petrochemicals

hydrogen and then undergo the complex molecular rearrangements necessary to form aldehyde and tricarbonyl in one step. It is reasonable to postulate that I reacts with hydrogen in the following manner before aldehyde is formed; Wender and co-workers at the Bureau of Mines have presented evidence that I and II have the structures indicated below[11]:



I



II

One might expect that the ease of formation of I will be influenced by the steric requirements of the olefin and that the rates of reaction of various olefins would depend on the configuration about the double bond. This effect is actually observed[11] and is illustrated in Table 2.

The straight-chain terminal olefin is least hindered and reacts most rapidly; the corresponding internal olefins react at about one-third this rate. However, the position of the double bond, as long as it is internal, has no effect upon the rate. Although 2,6-dimethylheptene-3 is doubly branched and has a double bond far removed from the terminal position, it reacts more rapidly than olefins lower in the table because there are no substituents at the double bond to offer steric interference to complex formation with the carbonyl. It is seen that the other olefins offer increased steric hindrance at the site of reaction and react at correspondingly decreased rates.

The oxo reaction rate doubles for a temperature rise[6] of C to 8 C. According to the temperature region considered, the apparent energy of activation appears to lie between 34 kilocalories (100-110 C.) and 29 kilocalories (110-120 C.).[6]

The effect of the solvent on the rate of hydroformylation of cyclohexene at 110 C. and 233 atmospheres of 1:1 synthesis gas is shown in Table 3.[11]

The solvent effect is not large, although it appears to be significant; the rate is increased about one and-a-half times in going from a saturated hydrocarbon to methyl or ethyl alcohol. The rate in aromatic solvents is greater than in aliphatic solvents; this effect may be due to the greater polarizability of the aromatic molecule, or to the greater basicity of the aromatic hydrocarbons. It is not likely that the variations in specific reaction rates with solvent are a reflection of the difference in solubility of hydrogen and carbon monoxide in the reaction media; hydrogen, for instance, is more soluble in paraffins than in aromatics of similar molecular weight.[12]

**Nature of the Olefin in the Intermediate Complexes**—The structure written for I is satisfactory for olefins which can have only internal or only terminal double bonds (ethylene, propylene, cyclohexene). We find, however, that although internal olefins are thermodynamically more stable than terminal olefins under reaction conditions, the products obtained in the hydroformylation reactions are largely derived by addition to the terminal carbons. It has been shown earlier that the distribution of alcohols secured from 1-pentene and 2-pentene is about the same, in each case the chief product, n-hexanol, can only be obtained by the addition of the formyl group to the number one carbon atom. If we assume that hydroformylation occurs only at the double bond, we may ask how it is possible to form a straight-chain aldehyde from an internal olefin.

These facts may be explained in the following manner, using 1-pentene and 2-pentene as examples. Because of steric hindrance, 2-pentene reacts with dicobalt octacarbonyl to form a complex more slowly than 1-pentene, and this accounts for the differences in rates observed with these olefins. It appears that the energy required for the rearrangement of the complex subsequent to its initial formation is small; we may therefore conclude that essentially the same complex is obtained from both terminal and internal olefins. The structure given for the olefin-carbonyl complex, I, probably represents the complex as it initially forms from either a terminal or internal olefin. It is not possible at present to write an adequate structure for the olefin-carbonyl complex as it exists a moment later, for the position of attachment of the unsaturated entity to the carbonyl is probably not fixed.

**TABLE 2**

**Effect of Olefin Structure on Rate of Hydroformylation at 110 C. and 233 Atmospheres of 1:1 $H_2$:CO**

| Olefin | Specific Reaction Rate, $10^3k$ min.$^{-1}$ |
|---|---|
| C–C–C–C–C = C | 66 |
| C–C–C–C = C–C | 19 |
| C–C–C–C = C–C–C | 19 |
| C–C–C–C = C–C–C | 6.2 |
| C C | |
| C–C–C = C–C | 4.9 |
| C | |
| C–C–C = C–C | 2.3 |
| C C | |
| C–C = C–C | 1.4 |
| C C | |

**TABLE 3**

**Effect of Solvents on the Rate of Hydroformylation of Cyclohexene at 110 C.**

| Solvent | Specific Reaction Rate, $10^3k$ Min.$^{-1}$ |
|---|---|
| Methylcyclohexane | 5.8 |
| Heptane | 5.9 |
| Methyl ethyl ketone | 5.7 |
| n-Butyl ether | 5.9 |
| Acetone | 6.1 |
| 2-Ethyl-1-hexanol | 6.5 |
| Chlorobenzene | 6.5 |
| Benzene | 6.7 |
| Anisole | 7.5 |
| α-Methylnaphthalene | 7.9 |
| Ethyl alcohol | 8.7 |
| Methyl Alcohol | 8.9 |

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# New Separation Tool—Low Temperature

**Here are details on three processes that prove the commercial feasibility of this new processing technique.**

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BILLIONS OF POUNDS of chemicals are produced annually through the use of low temperature separation and purification techniques. For the last two decades growth in production of materials by low temperature processing has been at a rapid pace, one which has resulted in the doubling of the total annual production about every four years. In 1955 3200 million pounds of ethylene were separated; (a portion only by low temperature processing) 2400 million pounds of high purity (99.5 percent) oxygen and 1320 million pounds of "tonnage" (95.0 percent) oxygen were produced; 190 million pounds of hydrogen were purified for synthetic ammonia production by liquid nitrogen scrubbing; and 23 million pounds of argon and 2.1 million pounds of helium were separated for use as inert gases. About 11 million pounds of carbon monoxide were produced and separated for chemical use.

**Diverse Low Temperature Separation Processes Have Features in Common**—Certain operations are to be found in any low temperature process without respect to the particular stream or fluid being handled. In processing gas, it must be compressed to an elevated pressure, a pressure sufficiently high that all the necessary refrigeration may be supplied to the system through subsequent Joule-Thomson expansion or by expansion of the stream through an engine or turbine. The **refrigeration requirements** thus **always necessitate compression,** which, in addition, in a relatively modest degree is required for movement of the stream through the various components of the plant.

Refrigeration is expensive at low temperatures and the lower the temperature, the more expensive. Resulting from this are the various types of highly efficient heat exchangers which make industrial low temperature work practical. **Low temperature work is characterized by large surface heat exchangers which operate at very small temperature driving forces.**

The heat exchangers must operate with high efficiency and can not tolerate the deposition upon their surface of materials which lowers the heat transfer coefficient or causes plugging of channels in the exchanger. This necessity of avoiding fouling adds another low temperature processing characteristic—**prepurification**—which constitutes the removal from the stream to be cooled of all materials which would otherwise be deposited within the heat exchanger. As an example, in the processing of air the most common impurities which cause heat exchanger blockage are water and carbon dioxide. Water vapor and carbon dioxide must be removed to avoid stoppage of the heat exchanger by their solid phases. Any material, **which is present in a stream in a greater concentration than its solubility limit or equilibrium partial pressure at the lowest temperatures to be encountered in the heat exchanger, must be treated as an impurity and removed.** The impurity removal, in some cases, is carried out externally of the cold box by chemical reaction, by absorption or by adsorption.

The heat exchanger in other cases will be so designed that it serves to remove the impurities. This can be done with a reversing cycle. In such cases the impurities deposit within the cold portion of the heat exchanger on the gas inflow portion of the cycle. Each impurity starts to deposit as a liquid or as a solid, as soon as the gas phase is cooled to the temperature at which it is saturated with respect to the particular impurity. The region in which the impurity will deposit can be predicted from knowledge of its vapor pressure and knowledge of the temperature distribution throughout the exchanger. In such a reversing heat exchanger, during the first part of the cycle the design heat capacity of the exchanger is used up in cooling the incoming compressed gas stream and removing its impurities **as deposited solids or liquids.** Then a cold, lower pressure, impurity free stream is passed through the same heat exchange passages in the reverse direction. This stream cools the heat exchanger, restoring its initial capacity of cold, and evaporates the previously deposited impurities.

The prepurification problem exists in all low temperature work. The character of the problem and its solution depends upon the temperature level and the materials in process. In the preparation of hydrogen for liquefaction, traces of oxygen may be removed by its catalytic reaction with hydrogen and the subsequent removal of the formed water on alumina. Traces of nitrogen may be removed

by adsorption on silica gel at liquid nitrogen temperatures.

**All low temperature processes require refrigeration** to balance the heat leak through the insulation and to balance the difference in heat content of the entering and leaving streams. This refrigeration may be added through the process stream itself or by means of a separate working fluid. If the process stream is used, low temperatures may be achieved through Joule-Thomson expansion of the gas or by expansion of the stream through an expansion engine or turbine. The gas in expanding does work, with the attendant removal of heat content and lowering of temperature.

A major application of low temperature processing is in the separation and purification of components of a gas or liquid stream. In all such applications **the knowledge of phase equilibria is of paramount importance.** This may involve mixed phase equilibria with or without adsorbents or absorbents.

Materials of construction are selected for their mechanical properties at low temperatures. Generally, corrosion is not a consideration in materials selection. The steels, low alloy steels, and iron become brittle at low temperatures and cannot be used under conditions where their failure would be a hazard to personnel or the process. **Copper, aluminum, stainless steels, nickel, nickelalloys, etc., are suitable materials for low temperature equipment.** The possibility of brittle failure makes not only the selection of suitable materials but the joint design and fabrication techniques of much importance.

In summary, we may note that all industrial low temperature separation processes will have the common features:

1. Compression of gas stream (major purpose—input of energy for subsequent refrigeration needs, minor purpose—to move stream through process equipment).

2. Large surface heat exchangers operating at very small driving forces.

3. Removal of dissolved impurities which would otherwise exceed their solubility limit during processing.

4. Introduction of refrigeration and

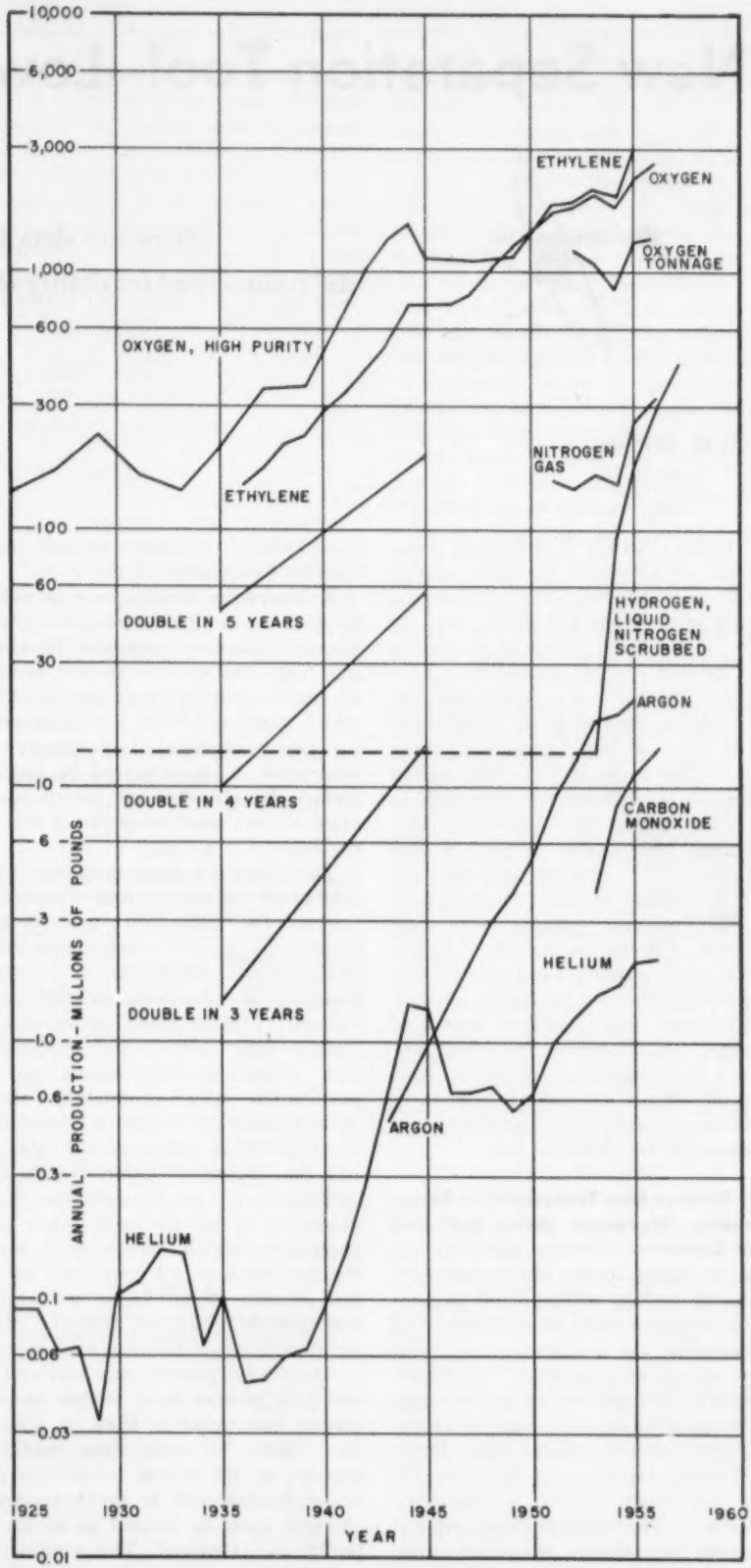


FIGURE 1—Annual production of ethylene, carbon monoxide, oxygen, helium, argon and nitrogen.

low temperatures through Joule-Thompson expansion, expansion through engines, or by expansion of a working fluid separate from the process stream.

5. Use of operations involving controlled use of phase equilibria such as separation, distillation, adsorption, and absorption.

6. Materials of construction selected to meet the required mechanical properties.

The discussion of individual processes later in this article will illustrate the appearance of the above features in actual operations.

**Special Analytical Problems**—Some products of low temperature purification plants are extremely pure, with the contaminants being present to the extent of only a few parts per million. These very high purities have required the development of very specific and sensitive analytical methods.

Trace quantities of oxygen or of hydrogen are found by catalytically combining that trace with an added excess of the other and noting the resulting temperature rise. Thermal conductivity is a powerful tool in many analyses, as in determining nitrogen in argon. The relative paramagnetic-diamagnetic properties of some gases allow this property to be used for analysis. The gas most frequently determined by use of this property is oxygen, since it differs radically from most all gases with which it may be associated.

A general approach which can be refined to any required sensitivity is that of concentrating the contaminant by "freeze-out" and subsequently analyzing the concentrate. This method can be used to determine traces of nitrogen in hydrogen, of carbon dioxide in air, of hydrogen sulfide in air or in hydrogen, etc. Any analytical method with the required sensitivity may be used in examination of the concentrated sample. For example, gas chromotography will serve to identify the impurity and establish its concentration in the main stream if it can be concentrated to 0.5 percent of the "freeze-out" concentrate. Mass spectrometry, infra-red, and the many specific chemical analyses may also be used in examination of the "freeze-out" concentrate.

Infra-red analysis of industrial streams for ppm quantities of carbon dioxide, nitrous oxide, carbon monoxide, acetylene, and hydrocarbon mixtures is employed on a widely increasing scale. Equipment designed specifically for single impurities is also in use, as for nitrogen oxides, for acetylene, and for water.

The emphasis has been upon continuous analysis since frequently the process will be controlled dependent upon the analytical results. Continuous monitoring also prevents any contamination of the product in storage as a result of momentary off-purity production.

**Storage and Transport**—The storage and transport of liquefied gases at low temperatures and pressures rather than their handling at ambient temperatures and high pressures offers economic advantages in some cases. Many factors must be appraised in the comparison of a liquid with a gas handling system. These include: distance of transport, rate of delivery required, relative density of the low temperature liquid and the high pressure ambient temperature gas, relation of heat capacity of transport equipment to sensible heat and heat of vaporization of the gas, road hazard, etc. Let's review current practice with each of the materials of Figure 1.

**Nitrogen** which is used in synthetic ammonia production is produced and purified at the ammonia plant site. There is no transport or storage problem. Some pure nitrogen is transported as a liquid in relatively small insulated vessels but most is used as gas in cylinders.

**Ethylene** is used at the production site or sent through pipelines as a gas to the consumer's plant site.[1] Serious consideration has been given in the U. S. to transport of ethylene as a liquid, but transport is presently all by pipeline as a gas. Ethylene has been transported as a liquid in the United Kingdom for several years.

**Oxygen** is produced, stored, and transported as both liquid and as gas. The economy of the specific situation determines which variant of the possibilities will be used. If liquid oxygen is required at the use site, then its transfer as a liquid from the point of production is a necessity. If gaseous oxygen is needed and it is not to be produced at the site of consumption, the economics may still favor its transport to the site as a liquid. This wastes the refrigeration represented by the latent and sensible heat of the oxygen but allows the payload portion of the total weight of the transport vehicle to be greater. Oxygen is currently transported as gas in cylinders and as liquid in insulated trucks and tank cars. The quantity of oxygen handled as a liquid greatly exceeds other low temperature liquids. The proportion of the total oxygen production which is handled as a liquid is increasing rapidly.

**Argon**, as with oxygen, is handled as both gas and liquid. Both argon and oxygen have the advantage of relatively high liquid densities from the view of liquid storage and transport.

**Carbon monoxide**, a relative newcomer to the low temperature field, is handled as a gas and used at the production site. Its poisonous character must always be kept in view in handling problems. Small quantities may be purchased in cylinders, but the major commercial use is from on-site production plants.

**Helium** is transported as a gas. Its very low density as a liquid and its very low critical temperature suggest that helium transport will remain gaseous except for special circumstances, as when liquid helium is required at the delivery end or where special weight considerations apply.

**Production Statistics**—The annual low temperature production of ethylene, oxygen, nitrogen, argon, carbon monoxide, and helium are shown in Figure 1 from 1925 to the present. Statistics used are those assembled by the U. S. Department of Commerce[3] and the U. S. Bureau of Mines,[4] except for carbon monoxide which is estimated. "Tonnage" oxygen was first reported in 1952, hence no earlier values are given. The use of pure carbon monoxide on large scale first became important in 1953. A portion only of the ethylene is produced by low temperature processing, but statistics are not available for this portion, so the total production is given.

It is a property of the semi-log plot which is used in Figure 1 that all lines with the same slope represent the same percentage increase (or decrease) in production. As an aid in

visually noting the rate of increase in production, lines are shown on Figure 1 with slopes corresponding to a doubling in production in 3, in 4, and in 5 years. It is seen that the production growths of argon and carbon monoxide are the most rapid, with ethylene and oxygen also growing very rapidly over a many year period.

The numbers of low temperature processing plants in operation in 1955 for each of the following materials are estimated to be:

| | |
|---|---|
| **Argon** | 20 |
| **Carbon monoxide** | 3 |
| **Ethylene** | 6 |
| **Helium** | 4 |
| **Hydrogen (nitrogen liquid scrub)** | 10 |
| **Methane** | 2 |
| **Nitrogen** | 200 |
| **Oxygen** | 400 |

We may expect continued rapid growth in each of the above items and within a few years will see added the commercial operation of denitrogenation of natural gas, perhaps with helium recovery.

**Industrial Processes in Use Today**—Examination of the industrial low temperature seperation processes being used today will illustrate the use of the same basic operations in each process. In reviewing the flow sheets and process discussion in the following, it will help to refer to Table 1, Physical Properties of Low Temperature Fluids.

**Oxygen, Nitrogen, Argon**—the three principal constituents of air—are obtained industrially by distillation. The atmospheric pressure boiling points are, in the following order, —297.3 F., — 302.6 F., — 320.5 F. (see Table 1). It is thus seen that the separation between nitrogen and argon is performed relatively more easily than is the separation between argon and oxygen. Further, in production of either oxygen or of nitrogen, argon will tend to be a contaminant since it boils between them. Thus, argon, if not produced as a separate component, will generally be separated into the stream which can tolerate it as an impurity.


**Meet the Author**

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Figure 2 demonstrates a high pressure air-liquid product-pump cycle for production of oxygen, nitrogen, and argon as pure components. In this particular cycle a portion only of the nitrogen is produced as a pure stream, the balance being produced as an impure stream contaminated with both oxygen and argon.

The air feed is compressed to an elevated pressure (point 1), the actual pressure in the range of 400 to 3000 pounds per square inch for the cycle shown being determined by the refrigeration requirements of the plant. It is then scrubbed with caustic solution (Point 2) and dried over alumina (Point 3). If the air source is clean, these two purification operations will suffice to remove the only contaminants—water and carbon dioxide—which would precipitate in and block the heat exchanger incoming-air passages. The purified air stream now enters the heat exchanger (Point 4) where it is cooled through heat exchange with the warming streams leaving the plant. A portion of the air stream is withdrawn (Point 5) from the heat exchanger after it is partially cooled and passed through an expansion engine (Point 6) where it is made to do work by expansion. Its temperature therefore drops, whereupon it is mixed with the other portion of the air, which has continued through the heat exchanger and has been expanded through a Joule-Thomson valve (Point 7).

The air, containing some liquid, enters the high pressure column (about 90 pounds per square inch absolute) where it is fractionated to produce nitrogen of the desired purity as top product and a bottoms liquid stream enriched in oxygen and argon.

**TABLE 1—Physical Properties of Low Temperature Fluids**

| NAME | Formula | Mol. Wt. | Normal Boiling Point °F | DENSITY AT NORMAL BOILING POINT | | | | TRIPLE POINT | | CRITICAL PROPERTIES | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Liquid | | Vapor | | | | | | Density | |
| | | | | lb ft $^{-3}$ | gcm $^{-3}$ | lb ft $^{-3}$ | g/l | Temp. °F | Press. psia | Temp. °F | Press. Atm | lb ft $^{-3}$ | gcm $^{-3}$ |
| Acetylene | $C_2H_2$ | 26.04 | —119 * | 38.7 | 0.620 | 0.104 | 1.66 | —114.6 | 17 | 97.4 | 61.6 | 14.4 | 0.231 |
| Ammonia | $NH_3$ | 17.03 | — 28.1 | 42.56 | 0.6818 | 0.0555 | 0.890 | —108.0 | 0.8813 | 270.32 | 111.5 | 14.7 | 0.235 |
| Argon | A | 39.94 | —302.6 | 87.4 | 1.40 | ..... | ..... | —308.7 | 9.99 | —187.60 | 48.0 | 33.2 | 0.531 |
| Carbon Dioxide | $CO_2$ | 44.01 | —109.3* | 94.4 | 1.512 | ..... | ..... | — 69.86 | 75.14 | 87.98 | 73.0 | 28.7 | 0.460 |
| Carbon Monoxide | CO | 28.01 | —312.6 | 50.6 | 0.81 | 0.27 | 4.4 | —337.1 | 2.23 | —218.20 | 34.6 | 19.4 | 0.311 |
| Deuterium | $D_2$ | 4.03 | —417.26 | 10.69 | 0.1712 | ..... | ..... | —426.0 | 2.48 | —390.82 | 16.28 | 4.17 | 0.668 |
| Ethylene | $C_2H_4$ | 28.05 | —154.8 | 35.2 | 0.564 | 0.126 | 2.01 | —272.5 | .017 | 49.8 | 50.50 | 14.2 | 0.227 |
| Helium | He | 4.00 | —452.1 | 7.62 | 0.122 | ..... | ..... | ..... | .... | —450.22 | 2.26 | 4.33 | 0.693 |
| Hydrogen | $H_2$ | 2.016 | —422.99 | 4.43 | 0.0709 | ..... | ..... | —434.5 | 1.044 | —399.82 | 12.8 | 1.94 | 0.0310 |
| Krypton | Kr | 83.70 | —244 | 135 | 2.18 | ..... | ..... | —250.9 | 10.62 | — 81.40 | 49 | 48.7 | 0.78 |
| Methane | $CH_4$ | 16.04 | —258.6 | 26.3 | 0.422 | 0.109 | 1.75 | —296.4 | 1.70 | —116.50 | 45.80 | 10.1 | 0.162 |
| Neon | Ne | 20.18 | —410.7 | 74.9 | 1.20 | ..... | ..... | —415.4 | 6.27 | —379.66 | 26.9 | 30.2 | 0.484 |
| Nitric Oxide | NO | 30.01 | —241.0 | 79.3 | 1.27 | ..... | ..... | —262.6 | 3.16 | —137.20 | 64.3 | 32.5 | 0.52 |
| Nitrogen | $N_2$ | 28.02 | —320.5 | 50.4 | 0.808 | ..... | ..... | —345.9 | 1.82 | —232.78 | 33.5 | 19.4 | 0.3110 |
| Nitrous Oxide | $N_2O$ | 44.02 | —127.2 | 76.8 | 1.23 | 0.19 | 3.1 | —131.6 | 12.74 | 97.7 | 71.7 | 28.1 | 0.45 |
| Oxygen | $O_2$ | 32.00 | —297.3 | 71.2 | 1.14 | ..... | ..... | —361.8 | .021 | —181.84 | 49.7 | 26.8 | 0.430 |
| Ozone | $O_3$ | 48.00 | —169.4 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Xenon | Xe | 131.30 | —163 | 191 | 3.06 | ..... | ..... | —169.4 | 11.82 | 61.88 | 58.2 | 72.1 | 1.155 |

*Denotes sublimation. **Volume of gas at 1 atm and 59F dissolving in unit volume of water, when equilibrium partial pressure of gas = 1 atm.

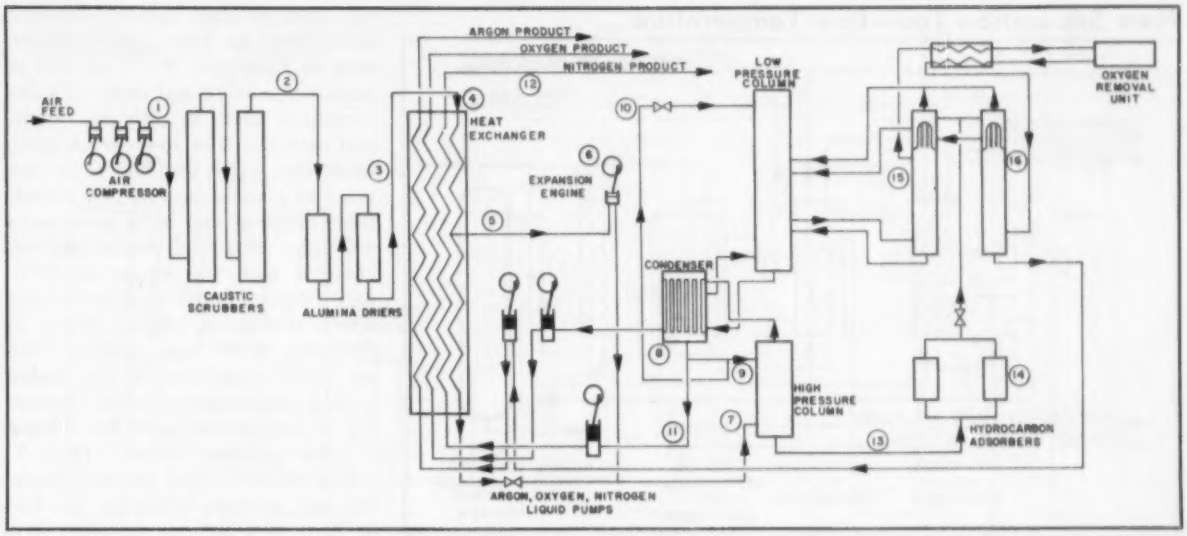


FIGURE 2—Oxygen, nitrogen, argon separation from air.

The nitrogen vapor is condensed at the high pressure column pressure by the cooling effect of the boiling (about 20 pounds per square inch absolute) oxygen product in the condenser (Point 8). If oxygen and nitrogen were boiling at the same pressure, the oxygen would be the warmer of the two, but in this case the oxygen is boiling at a much lower pressure and so is colder than the condensing nitrogen.

Some liquid nitrogen is returned to the high pressure column as reflux (Point 9), some is reduced in pressure and sent to the low pressure column as reflux (Point 10), and some is withdrawn as product (Point 11) and pumped as a liquid to the delivery pressure, evaporated, warmed to room temperature and withdrawn from the plant (Point 12). The bottoms from the high pressure column (Point 13) are passed through silica gel beds (Point 14) which remove dissolved hydrocarbons. This liquid stream is partially evaporated in the crude argon (Point 15) and pure argon (Point 16) columns where it produces reflux and then enters the low pressure column as a feed (Point 17).

A gaseous stream enriched in argon (Point 18) is drawn from the main low pressure column as feed to a "side arm" column (Point 15). A concentrated argon overhead product from this column is warmed to room temperature and treated for removal of oxygen. It is then recooled (Point 19), purified by distillation (Point 16), pumped as a liquid (Point 20), and warmed to room temperature in the main heat exchanger (Point 23).

Oxygen is also removed as a liquid and after being pumped to delivery pressure (Point 21) is warmed and withdrawn (Point 22). An impure nitrogen stream from the low pressure column is warmed and discharged as waste (Point 24).

**Hydrogen Purification by Liquid Nitrogen Scrubbing.** A hydrogen stream may be scrubbed with liquid nitrogen as a means of purification when the hydrogen is to be used for ammonia production. In this case a nitrogen content in the scrubbed hydrogen is not a disadvantage as it must be added anyway for ammonia manufacture. The liquid nitrogen scrubbing will remove all impurities to an extremely low level. The principal impurities are carbon monoxide, methane, and argon if the gas is obtained by the partial oxidation of natural gas. If the hydrogen is from a refinery or coke oven gas plant or obtained by partial oxidation of oil, other impurities will also be present, principally several low molecular weight hydrocarbons.

In Figure 3 it has been assumed that the water and carbon dioxide impurities have been removed from both the hydrogen and nitrogen gas streams and that these are delivered at the pressure used for the scrubbing operation. The hydrogen feed gas is cooled by counter current heat exchange with the hydrogen product from the scrub tower. As the hydrogen cools, hydrocarbons, if present, will condense and may be separated at separation pots (point 1). The

| Freezing Point °F | Specific Heat at 77 °F (Ideal) BTU/Lb. mol. °F | Latent Heat of Vaporization at N.B. Pt. BTU/mol. | Solubility in Water at 50 °F Ostwald coef** | GAS DENSITY AT 50° F AND 1 ATM | |
|---|---|---|---|---|---|
| | | | | lb ft⁻³ | g/l |
| ..... | 10.499 | 9180.0* | 1.37 | 0.07051 | 1.1294 |
| ..... | 8.523 | 10045.8 | 635 | .04642 | 0.7436 |
| ..... | 4.9680 | 2803.5 | 0.045 | .10737 | 1.7198 |
| ..... | 8.874 | 10854.0* | 1.238 | .11905 | 1.9070 |
| ..... | 6.965 | 2599.2 | 0.02732 | .07528 | 1.2059 |
| ..... | 6.98 | 540 | ..... | ..... | ..... |
| ..... | 10.41 | 5825.99 | 0.168 | .07615 | 1.2197 |
| —453.5 | 4.9680 | 39.60 | 0.0093 | .01066 | 0.1707 |
| 103 atm. | | | | | |
| ..... | 6.892 | 388.8 | 0.0202 | .00541 | 0.0866 |
| ..... | 4.9680 | 3884.4 | 0.0840 | .21940 | 3.5144 |
| ..... | 8.536 | 3519.0 | 0.04330 | .04316 | 0.6914 |
| ..... | 4.9680 | 792.0 | 0.0112 | .05247 | .8405 |
| ..... | 7.137 | 5952.6 | 0.0592 | .08071 | 1.2928 |
| ..... | 6.960 | 2404.8 | 0.0207 | .07532 | 1.2065 |
| ..... | 9.251 | 7110.0 | 0.969 | .11913 | 1.9082 |
| ..... | 7.017 | 2932.2 | 0.399 | .08605 | 1.3784 |
| —420 | 9.42 | 5184.0 | 0.015 | ..... | ..... |
| ..... | 4.9680 | 5436 | 0.180 | .34430 | 5.5149 |

## New Separation Tool–Low Temperature . . .

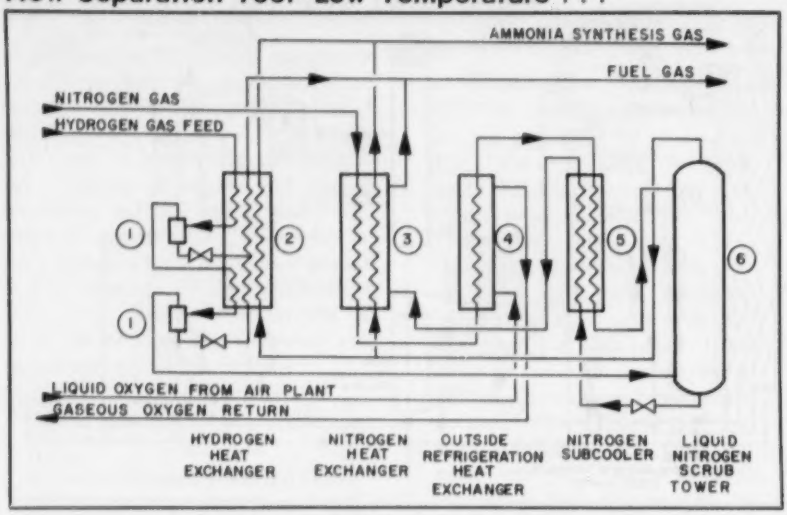


FIGURE 3—Hydrogen purification by liquid nitrogen scrubbing.

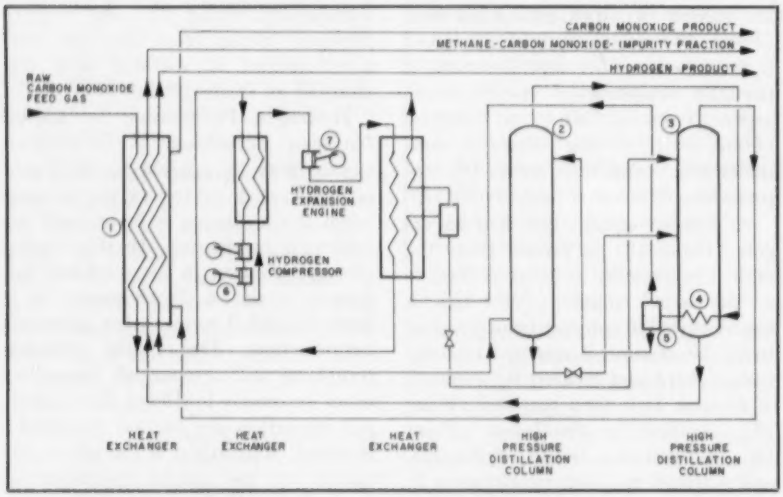


FIGURE 4—Carbon monoxide purification plant.

separated liquid phase is expanded and its refrigeration recovered. The gas phase enters the base of the scrub tower where its impurity is removed. The "key" impurity in the scrub tower is carbon monoxide, since its vapor pressure is almost as high as that of nitrogen. If the carbon monoxide is properly removed then also will be the methane, argon, oxygen and higher boiling impurities. The hydrogen overhead from the scrub tower, containing several percent of nitrogen, a few parts per million of carbon monoxide and extremely small amounts of other impurities, is warmed to ambient temperature against the cooling hydrogen and nitrogen feeds.

The nitrogen liquid which is fed to the scrub tower is produced by liquefaction of very pure nitrogen gas from an air separation plant. This gas is cooled by heat exchange with cold pure hydrogen (Point 3); liquefied by evaporation of a rich air liquid stream (Point 4); and then subcooled by heat exchange with the bottoms from the scrub tower (Point 5).

The bottoms from the scrub tower, containing substantial concentrations of methane, carbon monoxide, argon and other impurities dissolved in liquid nitrogen, are expanded and thus subcool the reflux liquid nitrogen, helping to reduce its flash loss as it is fed into the scrub tower.

**Carbon Monoxide Purification.** The flowsheet of Figure 4 illustrates the low temperature separation of 98.5 percent pure carbon monoxide from a feed gas containing 70-75 percent of hydrogen, 25-30 percent of carbon monoxide and traces of other impurities such as nitrogen, argon, and methane. The raw carbon monoxide feed gas is assumed to be supplied in a water and carbon dioxide free condition and at a pressure of 450 psig. This feed gas is heat exchanged with the separation products (Point 1) and then introduced into a distillation column (Point 2) operating at the feed pressure. Here an initial separation of the higher boiling components is made. Operating in conjunction with this column is a low pressure column (Point 3) which recovers more carbon monoxide and produces reflux for the first or high pressure column. The bottoms from the first column serve as feed to the second, following expansion. The overhead from the second column is passed to the main heat exchanger and removed as carbon monoxide product. The overhead gas from the first column is partially condensed (Point 4) in the base of the low pressure column to form reflux for the first column and boilup for the low pressure column. The vapor from the separation pot (Point 5) after further cooling and separation of condensate, is warmed to room temperature and removed as hydrogen.

Refrigeration is supplied to the system by the compression of hydrogen (Point 6) and its expansion (Point 7) at low temperature. Hydrogen for this service is supplied from the process stream and returned to it.

**Helium Separation and Purification.** The Bureau of Mines helium separation process[2] has been used for many years for the extraction of helium from natural gases. The process involves the liquefaction of substantially all of the natural gas constituents except helium and the separation of the gaseous helium from the condensed phase. Refrigeration is supplied principally through Joule-Thomson expansion of natural gas. An auxiliary nitrogen circuit involving nitrogen compression and expansion through an engine at low temperatures supplies the lowest temperatures and the needed make-up refrigeration.

Helium bearing natural gas, previously treated to remove water, hydrogen sulfide, and carbon dioxide

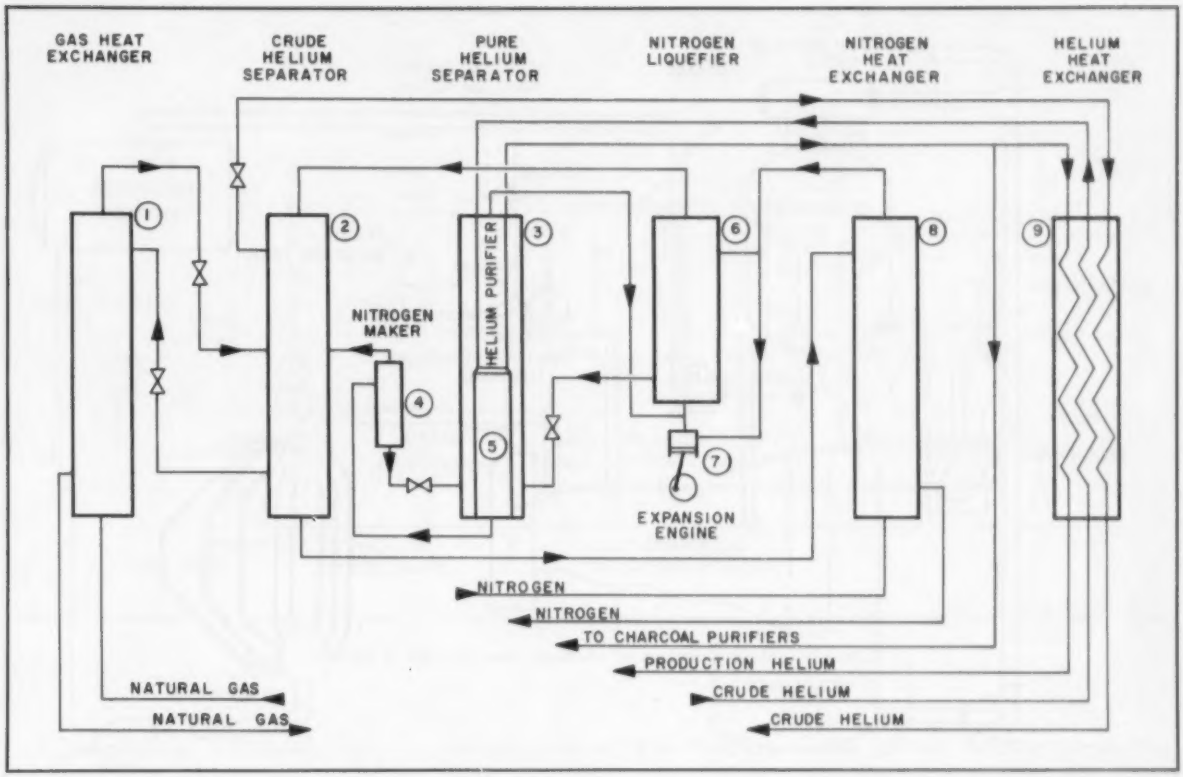


FIGURE 5—Bureau of Mines helium production.

and compressed to 600 psi, is cooled and partially condensed in the gas heat exchanger (Point 1). It is then throttled into the crude helium separator (Point 2) where, after further cooling with cold nitrogen gas, it is separated into a crude helium gaseous phase and a natural gas liquid phase. The liquid phase is evaporated in the gas heat exchanger and after compression returned to the pipe line. The crude helium is warmed to room temperature in the helium heat exchanger (Point 9), compressed to 2700 psi, and after recooling again subjected to partial liquefaction (Point 5) in a vessel cooled with liquid nitrogen. This liquid nitrogen is supplied by an auxiliary nitrogen liquefaction cycle. The gas phase formed in this second liquefaction is 98.5 percent helium and following heat exchange is removed as production helium.

The liquid phase resulting from this second liquefaction contains dissolved helium which is recovered in the separator (Point 4) connected to the crude helium separator. The liquid phase from this separation, mostly nitrogen, is used in cooling at Point 5 and returned to the nitrogen refrigeration circuit.

The 98.5 percent helium may be further purified by passage through charcoal at low temperatures. The impurities, mostly nitrogen, are removed and the helium purity raised to 99.7 percent or higher.

**Ethylene Purification.** Several processes are available (Reference 1 and PETROLEUM REFINER Petrochemical Process Handbook issues) and being used for ethylene formation. A hydrocarbon feedstock may be thermally cracked to provide ethylene in a mixture with hydrogen and other hydrocarbons, or it may result from thermal or catalytic cracking operations designed for gasoline or other oil production. The thermal cracking may involve several variants, such as cracking in externally fired tubular coil, in pebble heaters, refractory checker heaters, and in partial-oxidation reactors.

The ethylene, from whatever source, must be purified before it is subjected to low temperature purification. It is necessary to remove hydrogen sulfide, carbonyl sulfide, water, acetylene, and carbon dioxide. These impurities are removed by scrubbing, adsorption, or freeze-out.

After purification the ethylene bearing stream is fractionated to remove methane and hydrogen as light materials and C4's and heavier. The principal separation problem is between ethylene and ethane. Often the ethane is recycled to the cracking unit to produce more ethylene. The ethylene-ethane separation may be made by straight distillation at low temperatures and pressures, with the refrigeration being supplied by ethylene or ethane as the low temperature working fluid. In such cases a cascade arrangement will be used, the ethylene being condensed with a higher temperature material such as propane and it, in turn, being condensed with cooling water.

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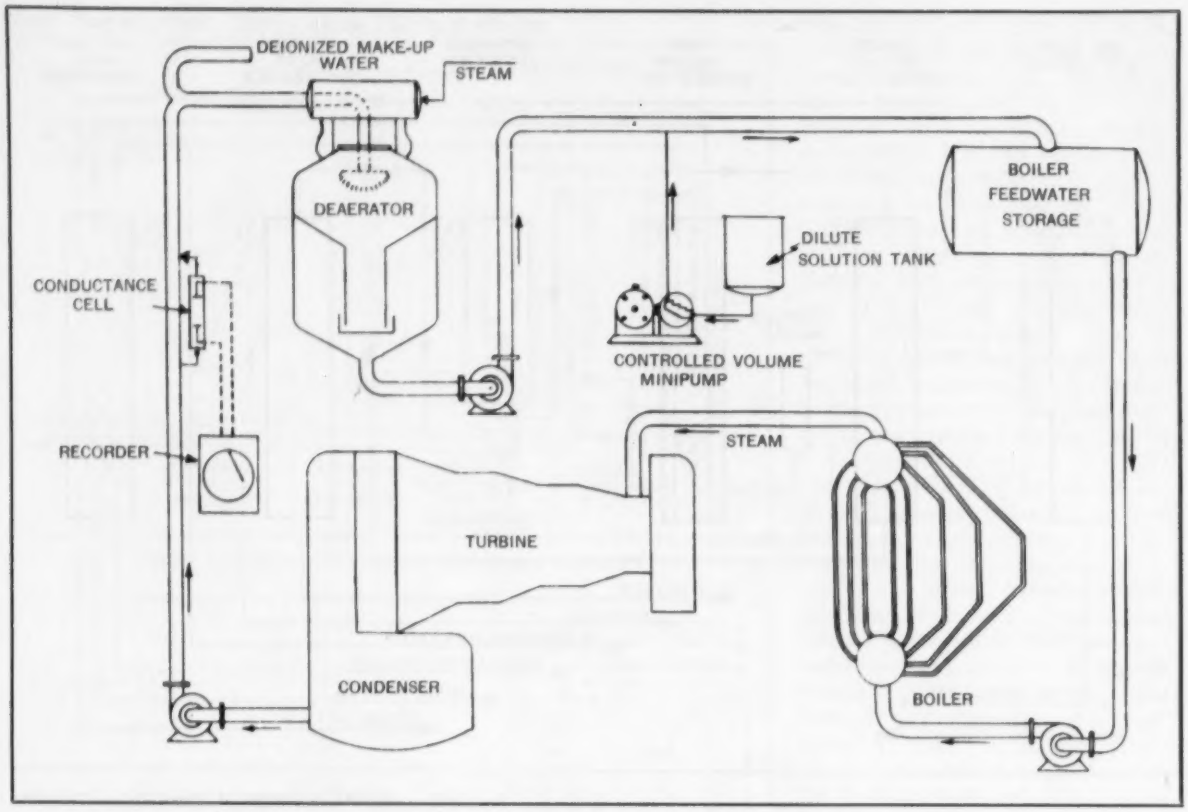


FIGURE 1—Single pump assembly for feeding hydrazine solution to steam-water cycle.

# Hydrazine Cuts Water Treating Costs

**A vast improvement over sodium sulfite in boiler feedwater treatment, hydrazine removes oxygen more efficiently without adding solids.**

**E. R. Woodward**
Olin Mathieson Chemical Corporation
New York City

IN THE OPERATION of all types of steam generating equipment, the chief causes of depreciation, repairs and inefficient operation are corrosion and scale. To control these conditions, modern science of boiler operation calls for conditioning of the feedwater.

The ideal treatment would produce water of slight alkalinity, zero dissolved solids and complete absence of free oxygen. In customary practice, chemicals control acidity; evaporation or ion exchange resins remove dissolved solids; and preheating the feedwater and adding sodium sulfite reduce oxygen content. These methods have greatly lessened corrosion and scale.

In the area of oxygen removal, however, there is much room for improvement. Sodium sulfite eliminates oxygen only if used to considerable excess. Further, sodium sulfite adds dissolved solids either as the original sodium sulphite or as sodium sulfate after reaction with oxygen. These dissolved solids are a serious disadvantage, particularly in the new higher pressure boilers. In all installations, the rising costs of equipment and repairs have made complete removal of free oxygen from feedwater

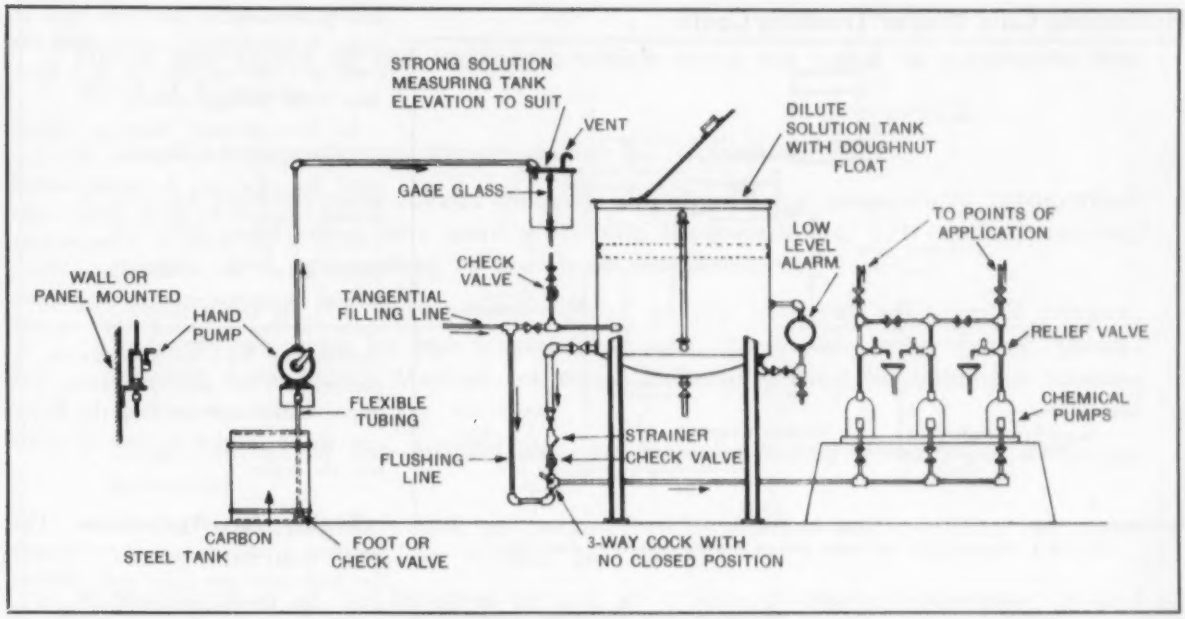


**FIGURE 2—Multiple-pump assembly for applying hydrazine solution.**

an urgent necessity. Fortunately, hydrazine is now commercially available and offers a better answer to oxygen elimination.

Hydrazine ($N_2H_4$), a clear, water-white, alkaline liquid with an ammonia-like odor reacts with oxygen to form nitrogen and water. Theoretically one pound of hydrazine reacts with one pound of oxygen. Boiler operators have found, however, that less than one pound of hydrazine will eliminate the corrosive effect of one pound of dissolved oxygen. Moreover, hydrazine, neither in its original form nor through its reaction products, adds any dissolved solids. In these two important respects, therefore—in deoxygenating more efficiently and in **not** adding solids—hydrazine is a vast improvement over sulfite.

There are also important corollary benefits in using hydrazine. These are:

- Hydrazine contributes desired alkalinity to the water (1 percent solution has a pH of 9.9).
- Hydrazine improves heat transfer by reducing ferric oxide scale in the boilers to magnetic iron oxide.
- Hydrazine, being used in very low concentrations, takes little storage space and little handling labor.
- Hydrazine effects a saving in actual material cost. Usually the hydrazine needed to remove oxygen costs less than the sodium sulfite it replaces.

Thorough testing and experience have proved that there are no disadvantages of any consequence in using hydrazine.

The first use of hydrazine in boiler feedwater in this country was in 1951. Although this use of the product was still under development in 1955, known users in that year included 44 utility plants, 10 industrial plants, and 13 buildings and apartments. Large installations, which represent the largest investments and operating responsibilities, make up the largest group of present users. Hydrazine is now protecting utility plant boilers worth an estimated total of $200 million.

The concentration of hydrazine recommended for boiler feedwater treatment is a 35 percent aqueous solution. In this form hydrazine is stable and non-flammable and is shipped in non-returnable containers.

Some large users of hydrazine have been taking deliveries in a more concentrated solution which involves much greater handling precautions. This more concentrated material also must be shipped in stainless steel returnable containers on which a substantial deposit is required.

With the 35 percent solution there is no unusual handling hazard; the only precautions necessary are those customary in handling strong alkalies.

**Hydrazine Dosage**—The question of how much hydrazine is required in any given boiler can be answered when it is known how much dissolved oxygen is contained in the incoming feedwater.

If the feedwater is not mechanically deaerated it may contain up to 8 parts per million of dissolved oxygen. On the other hand, if the feedwater is deaerated and the deaerator is operating efficiently, the feedwater at the effluent of the deaerator may contain dissolved oxygen from a lower limit of 0.005 ppm up to 0.1 ppm depending upon the type of deaerator in use.

In any event, the dissolved oxygen content of the feedwater at the discharge of the deaerator or at the discharge of the feedwater pump should be determined by taking water samples at one of these points. If the oxygen content is 0.04 ppm or more

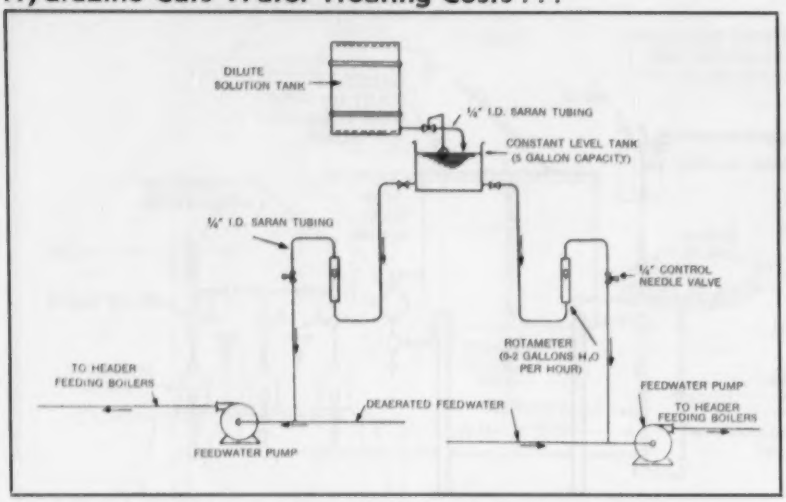


**FIGURE 3—Application of hydrazine solution to pump suctions by gravity feed.**

the Winkler Method can be used. For lower values of dissolved oxygen the ASTM D-888-49-T Method is recommended.

In theory, 1 pound of hydrazine is required to remove 1 pound of dissolved oxygen. This fact can be used as a basis for determining how much hydrazine should be added to boiler feedwater for oxygen removal.

After a hydrazine residual has been established, the initial feed rate can sometimes be reduced without losing the protection of the desirable hydrazine residual in the boiler. Cleanliness of the boiler has a direct effect upon the rapidity with which the initial hydrazine residual is produced.

In a tight system there is some recirculation of hydrazine, so there may be a slight build-up in the boiler. That is another factor which tends to reduce the required dosage once a residual is present and after the system has been conditioned with hydrazine. Under these circumstances it has been found that the addition of hydrazine in quantities less than the theoretical is sufficient to afford ample protection from internal corrosion.

**Application of Hydrazine**—For use in industrial plant boilers, hydrazine solution is usually fed continuously into the feedwater line between the outlet of the deaerator and the intake of the boiler feedwater storage tank. With this arrangement a chemical proportioning pump is used to inject the hydrazine solution into the feedwater line against the back pressure of the flowing stream.

In low pressure heating boilers, hydrazine solution is most simply applied batchwise. A double-valved piping connection can be fitted to the outside of the boiler at a convenient point above the water line. When adding hydrazine solution, the upper valve is opened and the correct amount of hydrazine solution is poured into the pipe. By closing the upper valve and opening the lower one the hydrazine is then dropped into the boiler.

**Testing for Hydrazine**—The simplest types of testing equipment for hydrazine are color comparators now available for determining hydrazine content of boiler feedwater in fractional parts per million. These are relatively inexpensive, being in the price range of other color comparators widely used for pH measurements, orthotolidin test sets (for available chlorine), and the like.

Precision instruments for determining hydrazine are also available, including a hydrazine recorder. This type of equipment is considerably higher-priced and is applicable generally to larger boiler installations.

**Handling Precautions**—Although high concentrations of hydrazine can be ignited, solutions containing 40 percent $N_2H_4$ or less have no flash point.

Direct contact of hydrazine with the skin, and also inhalation of the vapors, should be avoided. Some individuals who are allergic develop dermatitis upon prolonged contact with small amounts of hydrazine. For this reason, if hydrazine solution is spilled on the skin it should be flushed off at once with plenty of water.

In general, if sufficient ventilation is provided to prevent a noticeable odor of hydrazine, no exposure damage will be suffered. In our own operations for the manufacture and testing hydrazine our men have handled large quantities of this chemical over a period of several years with no ill effects. ##

**Meet the Author**

ERIC R. WOODWARD is a chemical engineer for Olin Mathieson Chemical Corporation in Baltimore. He joined the Mathieson Alkali Works, Inc., now Olin Mathieson, in 1941 as a development engineer after receiving his degree in chemical engineering from McGill University, Montreal, Canada. In conjunction with the research staff of General Mills, Inc., Woodward developed on a plant scale, the use of chlorine dioxide as a wheat flour bleach. For the past few years, he has been devoting his time to working on new uses for hydrazine and its derivatives, with particular emphasis on its use in industrial water treatment. He has been invited to present a paper on this subject at an international meeting to be held at Bournemouth, England, in May, 1957.

**These are some of the methods which may be used to evaluate the Merkel Equation . . .**

- **Graphic integration by planimeter or by rectangular count.**
- **Use of performance curves already developed by graphically integration for the most commonly used wet bulb temperatures, L/G ratios, cooling ranges, and approaches to wet bulb temperatures.[7]**
- **Summation of the incremental values of the integral over small ranges. Determining area by the trapezoidal rule, Simpson's Rule, Cotes' Three-eighths Rule, Gauss Method, or other commonly used formulas for numerical integration.**
- **Simplification of the Merkel Integral by substituting a log mean enthalpy potential.**
- **Use of a nomograph such as constructed by Merkel and modified for more convenient use later by Woods and Betts.[8]**
- **Modification of the integral by use of a second degree polynonial to approximate the saturation line over the range of inlet and outlet water temperatures. This modifies the integral so that it can be directly integrated for determination of KaV/L.[9]**

# Computer Evaluates Cooling Towers

**An accurate and speedy method is described in which a digital computer is used to evaluate and design countercurrent cooling towers.**

**A. L. Fuller**
The Fluor Corporation, Ltd.
Whittier, Calif.

THERE IS A GROWING demand for cooling towers in the industry. Not only are these towers required to supply more and more water, but they are called upon to supply this water at temperatures very closely approaching the wet bulb temperature of the surroundings. Therefore, sound methods are needed to analyze and predict cooling tower performance.

An accurate and time-saving method is described here for correlating countercurrent cooling tower performance by using high speed electronic digital computers. The method employs the widely accepted Merkel Integral and solves this integral by using Simpson's Rule.

**The basic equation** considers enthalpy as the driving force, and was developed first by Merkel[1] in 1925, and later by Nottage.[2] Two assumptions used in the Merkel equation are as follows:

1) The Lewis[3] relationship is valid.

$$\frac{h_g}{Ks} = 1$$

Sherwood and Comings,[4] and London, Mason and Boelter[5] generally agree that this relationship holds for water-air mixtures at moderate and low humidities. Koch,[6] however, concludes that the ratio is more nearly equal to 0.9. In any event, the possible error involved in

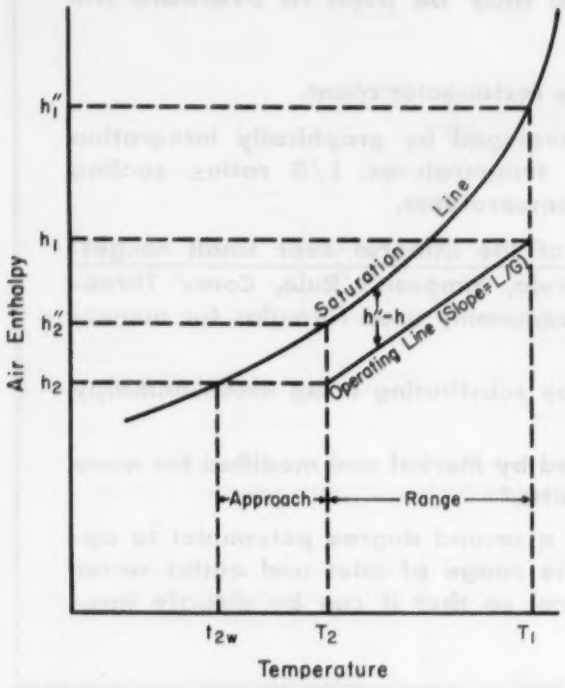


FIGURE 1—The operating line for a given cooling process may be established from simple test data.

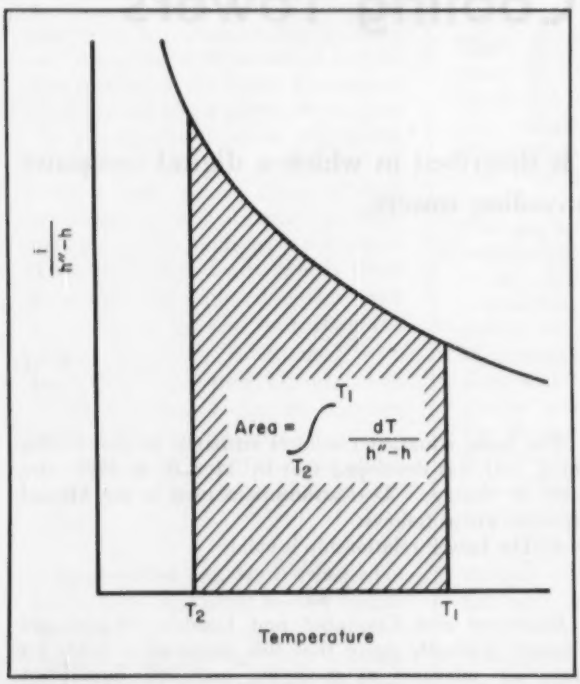


FIGURE 2—The integral may be represented as the area under the curve. A method is proposed here for using a computer to calculate this integral quickly and accurately.

using this assumption in the Merkel Equation would be small—on the order of 1-2 percent.

2) The air enthalpy can be expressed as $h = st + rW$. The error involved in this assumption is generally considered within the precision of data measurements.

With these basic assumptions, the Merkel counterflow cooling tower equations were developed:

$$L\,dT = K\left[\frac{h_z}{K}(T-t) + r\,(W''-W)\right] a\,dV.$$
$$= K\left[(sT + r\,W'') - (st + r\,W)\right] a\,dV.$$
$$= K\,(h''-h)\,a\,dV. \quad (1)$$

From a heat balance over a differential tower height

$$L\,dT = G\,dh \quad (2)$$

Rearranging and integrating Equation (1):

$$\frac{Ka\,V}{L} = \int_{T_2}^{T_1} \frac{dT}{h''-h} \quad (3)$$

**To illustrate the principles** and to show the relationships involved in this concept of cooling performance, refer to the plot of air enthalpy versus water temperature shown in Figure 1. This shows the air saturation enthalpy curve, the tower inlet and outlet air and water conditions, and the tower operating line (slope = L/G).

From test data for $T_1$, $T_2$, $t_{2w}$, L and G, it is possible to establish the operating line ($t_{2w}$ fixes $h_2$ since enthalpy of moist air is a function of the wet bulb temperature). The conditions at the top and bottom of the tower are represented by the points ($T_1$, $h_1$) and ($T_2$, $h_2$), respectively. The enthalpy potential or driving force at the top of the tower is shown as the difference between $h_1''$ and $h_1$; at the bottom of the tower as the difference between $h_2''$ and $h_2$; and at any level between the top and bottom as the difference between h″ and h.

The integral $\int_{T_2}^{T_1} \frac{dT}{h''-h}$ would then be the area under the curve of $\frac{1}{h''-h}$ versus temperature between the limits of $T_2$ and $T_1$. This area is illustrated in Figure 2 by cross-hatching. The area may be evaluated by any one of the several methods described in the accompanying box.

All of these methods, when calculated by conventional means, are either complicated and time consuming or lack the desired accuracy required in the evaluation of present day cooling performance. A quick and accurate method for solving Merkel's Equation (3) is desirable and essential in the development and design of evaporative cooling apparatus.

The author selected the third method listed in bold type as the basis for machine calculation of cooling tower performance. This method represented a basic and straightforward approach to solving the Merkel Equation. It was then necessary to determine which of the commonly used numerical integration methods would be most suitable for machine calculation.

The trapezoidal rule is straightforward from a computation standpoint but somewhat lacking in accuracy. The Cotes Rule and Gauss Method are somewhat more accurate than Simpson's Rule but not quite as simple in

form. Therefore, Simpson's Rule was selected for evaluating the Merkel Integral because it combined the simplicity of form with adequate accuracy.

Simpson's Rule sums incremental areas using a second degree polynomial for representation of the confining curve of each pair of incremental areas.

**With the high speed** calculations of the electronic digital computers, it is possible to solve Simpson's Rule by as many increments as is needed for accuracy. For example, 10 intervals can be solved in approximately 5 seconds, 20 intervals in approximately 10 seconds on some of the present day computers.

A rather complete study was made to determine the number of increments necessary in Simpson's Rule to give the desired accuracy. Some of the cases are shown in Table 1.

**TABLE 1**
**Comparison of KaV/L Calculations Using Simpson's Rule With Number of Temperature Intervals Ranging from 4 to 90**

| $T_1$ (°F) | $T_2$ (°F) | $t_{2w}$ (°F) | L/G | No. of Temp. Intervals | Ka V/L |
|---|---|---|---|---|---|
| 120 F. | 90 F. | 85 F. | 1.500 | 4 | 3.1675 |
| | | | | 6 | 3.1651 |
| | | | | 8 | 3.1638 |
| | | | | 10 | 3.1647 |
| | | | | 50 | 3.1646 |
| | | | | 90 | 3.1641 |
| 87 F. | 77 F. | 75 F. | 1.000 | 4 | 4.2141 |
| | | | | 6 | 4.2140 |
| | | | | 8 | 4.2113 |
| | | | | 10 | 4.2140 |
| | | | | 50 | 4.2140 |
| | | | | 90 | 4.2134 |
| 130 F. | 80 F. | 70 F. | 0.500 | 4 | 1.8705 |
| | | | | 6 | 1.8668 |
| | | | | 8 | 1.8659 |
| | | | | 10 | 1.8659 |
| | | | | 50 | 1.8658 |
| | | | | 90 | 1.8652 |
| 110 F. | 90 F. | 60 F. | 3.000 | 4 | 1.5682 |
| | | | | 6 | 1.5662 |
| | | | | 8 | 1.5659 |
| | | | | 10 | 1.5658 |
| | | | | 50 | 1.5658 |
| | | | | 90 | 1.5657 |

As a result of the many machine calculations, the author has found that generally good accuracy can be obtained by solving the Merkel Integral using Simpson's Rule with six or eight equal temperature increments. However, in order to insure a consistently high degree of accuracy for all cooling jobs, a standard number of ten increments was selected for the machine calculation method.

**A complete program** has been developed to calculate cooling tower performance from test data obtained from the Research evaporative cooling test apparatus of the author's company. This program has been machine coded for two medium-priced electronic computers. Both computers calculate in a very few seconds the KaV/L from known rates and temperatures of the air and water circulating in the test apparatus.

This program was developed to process data from a test unit and as such was designed to serve three functions, namely:

1. Determination of air and water mass flow rates from uncorrected input data.
2. Determination of a heat balance around the test apparatus.
3. Determination of KaV/L (numerical integration of Merkel Equation using Simpson's Rule).

The first two functions of the machine calculation are

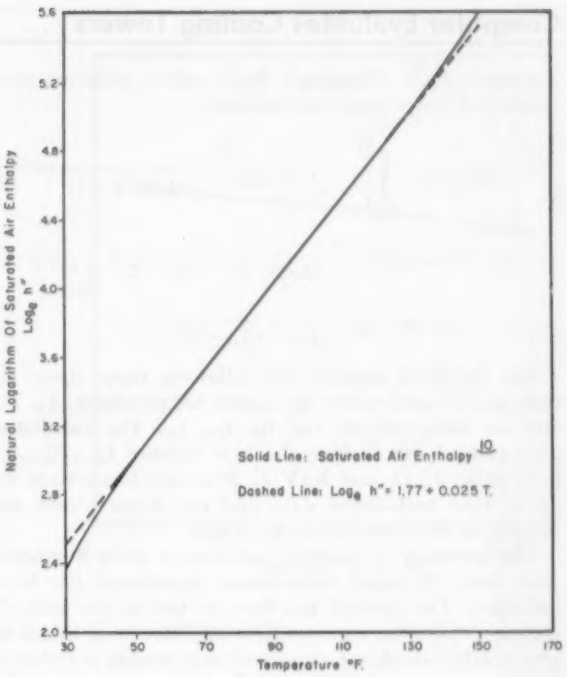
Natural Logarithm Of Saturated Air Enthalpy
Log$_e$ h″
Solid Line: Saturated Air Enthalpy [10]
Dashed Line: Log$_e$ h″= 1.77 + 0.025 T
Temperature °F.

**FIGURE 3—The equation for enthalpy is valid for temperatures between 40 F and 130 F. Outside this range, the accuracy of the equation falls off rapidly.**

straightforward calculations of inlet and outlet air humidities, specific volumes, and enthalpies. With these values and the known air and water rates, a heat balance around the test apparatus is determined. This serves as a check on the accuracy of the test data and the instrumentation. In addition, the calculated air and water mass flow rates and air enthalpies are stored for use in the KaV/L calculation which is the third and most important function of the program.

In the KaV/L calculation, the enthalpy driving force, $h'' - h$, is represented by expressions relating the air enthalpy at saturation and the air enthalpy at conditions set by the operating line (with slope L/G) to corresponding water temperatures. The mathematical expression relating saturation air enthalpy with temperature was determined recently by Butcher.[9]

$$\ln h'' = 1.77 + 0.025T$$
$$\text{or} \quad h'' = e^{1.77 + 0.025T} \tag{4}$$

This equation holds for temperatures between 40 F. and 130 F. At temperatures outside this range, the accuracy of the equation falls off rapidly. A plot showing the coincidence of points calculated by Equation (4) with the standard air saturation curve is shown in Figure 3. With the substitution of this expression for saturation enthalpy and other expressions relating temperature with enthalpy at operating conditions of the tower, the following integral is obtained:

$$KaV/L = \int_{T_2}^{T_1} \frac{dT}{e^{1.77 + 0.025T} - (L/G)T + C} \tag{5}$$

where $C = (L/G)T_2 - e^{1.77 + 0.025t2w}$

With this expression of Merkel's Integral, it is now possible to proceed with the numerical integration of

## Computer Evaluates Cooling Towers . . .

Simpson's Rule (Simpson's Rule utilizes only an even number of temperature increments).

$$KaV/L = \int_{T_2}^{T_1} \frac{dT}{e^{1.77 + 0.025T} - (L/G)T + C} \cong \frac{\beta}{3}\left[\frac{1}{e^{1.77 + 0.025T_1} - (L/G)T_1 + C}\right.$$

$$+ \frac{4}{e^{1.77 + 0.025(T_1 - \beta)} - (L/G)(T_1 - \beta) + C} + \frac{2}{e^{1.77 + 0.025(T_1 - 2\beta)} - (L/G)(T_1 - 2\beta) + C}$$

$$\left. + \frac{4}{e^{1.77 + 0.025(T_1 - 3\beta)} - (L/G)(T_1 - 3\beta) + C} + \ldots + \frac{1}{e^{1.77 + 0.025T_2} - (L/G)T_2 + C}\right] \quad (6)$$

The program requires the following input data: air rate, uncorrected; water rate; water temperatures, $T_1$, $T_2$; and air temperatures, $t_{1w}$, $t_{1d}$, $t_{2w}$, $t_{2d}$. The calculated data printed out include the heat balance $Q_{air}/Q_{water}$, L/G ratio, L, G, and KaV/L. Print-out forms were set up so that both input data and calculated results are printed on the same line for each case.

**The accuracy** of machine calculation using Simpson's Rule with 10 equal temperature increments has been indicated. The method has been in use at the author's company for over eight months and has been found to give results which are consistent and readily correlated. In general, the method described compares favorably with the Graphic Integration Method described by Lichtenstein.[7] Other methods, for the most part, give performance results which are slightly low. This point is illustrated in Table 2.

**TABLE 2**
**Comparison of Several Methods for Evaluating Cooling Tower Performance**

| | 1. | 2. | 3. | 4. | 5. |
|---|---|---|---|---|---|
| **A. Operating Conditions** | | | | | |
| $T_1$ Inlet Water, F. | 100.0 | 87.0 | 130.0 | 120.0 | 110.0 |
| $T_2$ Outlet Water, F. | 80.0 | 77.0 | 80.0 | 90.0 | 90.0 |
| $t_{2w}$ Inlet Air Wet Bulb, F. | 60.0 | 75.0 | 70.0 | 85.00 | 60.0 |
| L/G Water to Air Mass Ratio | 1.000 | 1.000 | 1.400 | 1.500 | 3.000 |
| **B. Performance Index, KaV/L** | | | | | |
| Machine Calculation Method, (Simpson's Rule @ 10 intervals) | 1.015 | 4.214 | 3.933 | 3.165 | 1.566 |
| Log Mean Enthalpy Potential | 0.954 | 3.884 | 2.002 | 2.189 | 1.377 |
| Woods and Betts Nomograph | 0.99 | 4.5 | * | * | 1.20 |
| Graphic Integration | 1.021 | 4.3 | 4.1 | 3.17 | 1.60 |
| **C. KaV/L Deviation from Machine Method, Percent** | | | | | |
| Machine Calculation Method, (Simpson's Rule @ 10 intervals) | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Log Mean Enthalpy Potential | −5.9 | −7.8 | −49.1 | −30.8 | −12.1 |
| Woods and Betts Nomograph | −2.4 | +6.8 | * | * | −23.4 |
| Graphic Integration | +0.7 | +2.0 | +4.3 | +0.2 | +2.2 |

*Cooling range too large for nomograph.

The computer program as originally set up was intended for use with a specific test installation. However, the program has since been extended to calculate either countercurrent or crossflow performance on all sizes of cooling towers. The extended program is useful in development and design work, in rating, and in evaluating performance guarantee tests.

In the extended program, the crossflow correlation method[9] used is an extension of the basic theory already described. It uses two simultaneous differential equations (one in the direction of water flow and the other in the direction of air flow) to represent the more complex heat transfer situation.

### SYMBOLS USED

a = total interfacial area per unit packed volume of tower, sq. ft./cu. ft.
e = base of natural or Naperian logarithms.
G = mass velocity of air, lbs. dry air/(hr.) (sq. ft. of tower cross section).
h = enthalpy of air, BTU/lb. of dry air.
h″ = enthalpy of saturated air at the air-water interface temperature, BTU/lb. of dry air.
$h_g$ = coefficient of thermal transfer across gas film, BTU/(hr.) (sq. ft.) (F.)
K = coefficient of mass transfer, lb (hr) (sq. ft.) (unit humidity potential in lb., or Btu/(hr) (sq. ft.) (unit enthalpy potential in Btu/lb.
L = mass velocity of liquid (water), lb/(hr)(sq. ft. of tower cross section).
r = latent heat of vaporization, BTU/lb.
s = humid heat, BTU/(lb. dry air) (F.)
t = air temperature, F.
T = water temperature, F.
V = packed tower volume, cu. ft./sq. ft.
W = air humidity, lb. water vapor/lb. dry air.
W″ = humidity of saturated air at the air-water interface, lb. water vapor/lb. dry air.
$\beta$ = defined as $\frac{T_1 - T_2}{\text{(Number of equal increments)}}$

**Subscripts**

1 = conditions at water inlet or air outlet end of counterflow tower.
2 = conditions at water outlet or air inlet end of counterflow tower.
w = air wet bulb temperature.
d = air dry bulb temperature.


### ACKNOWLEDGMENT

The author wishes to express appreciation to Fluor Products Company and to The Fluor Corporation, Ltd., for permission to publish this paper, and to the many persons in the Research division for their contributions and cooperation.


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### Meet the Author

A. L. FULLER is in charge of cooling tower research conducted for the Fluor Products Company by the research division of The Fluor Corporation, Ltd. He graduated from the University of Southern California in 1943 with a B.E. degree in chemical engineering, then served four years during World War II in the Navy as chief engineer on destroyer escorts. Following this, he joined the General Electric Company, Anaheim plant staff where he worked as process engineer and production schedule and quality control supervisor. In 1951, he joined Fluor where he worked initially with sulfur and gas treating plants. Fuller has been actively engaged in research in evaporative water cooling since 1952 and was promoted to his present position in 1955.

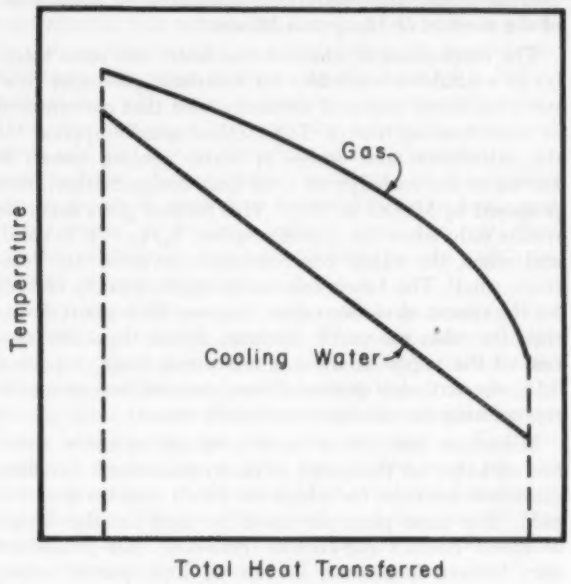


FIGURE 1—Total heat transferred for gas and water versus temperature.

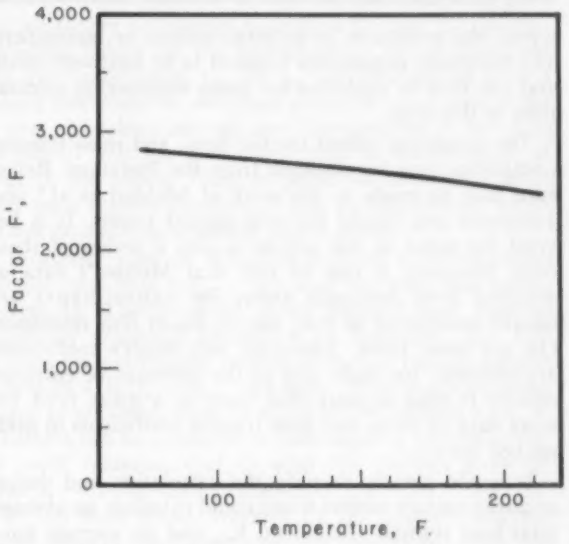


FIGURE 2—The factor F' for various temperatures, used in the example.

# Design Direct Contact Coolers Quickly

**This simplified method will aid in applying this useful processing tool to many cooling problems in your plant.**

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THE COOLING of hot saturated gases by direct contact with cold liquids has found large-scale applications in petrochemical plants.

Direct contact coolers are especially suitable for the handling of dusty gases. These gases would cause difficulties in tubular cooler-condensers. The direct contact coolers are also desirable for operation with corrosive cooling water or corrosive gases. However, in some cases the recovery of the cooling water or its disposal may cause difficulties due to objectionable substances absorbed during cooling.

Direct contact coolers are usually built as packed towers, spray towers or wetted wall towers.

A new method for the calculation of scrubber-coolers for saturated gas-vapor mixtures will be presented here which is similar to the design method for tubular cooler-condensers recently published by the author.[1]

**Design of Scrubber-Coolers**—The rate of cooling in a direct contact cooler is governed by the mechanism of simultaneous heat- and mass transfer. The differential equation for the total heat transfer can be written,

$$dQ = h_g (t_g - t_w)\, dA + k_c (p_v - p_w)\, dA\, \lambda_w = h_t (t_g - t_w)\, dA \quad (1)$$

or

$$A = \int dA = \int \frac{dQ}{h_t (t_g - t_w)} \quad (2)$$

Equation (2) is valid under the assumption that the surface for heat transfer is equal to the surface for mass transfer. This will be the case in spray towers, wetted wall towers, and packed towers with completely wetted packing surfaces. Complete wetting of the packing is easily achieved in towers packed with wood grids or similar packing. However, it is generally believed that Raschig rings, Berl saddles and similar packings are never completely wetted at liquid flow rates up to the flooding point. For the purpose of this discussion, it will be assumed that the area available for heat- and mass transfer are equal.

Equations (1) and (2) ignore the liquid film resistance. Actually, little is known about the magnitude of the

liquid film resistance in scrubber-coolers or humidifiers. The resistance is generally believed to be relatively small, and can thus be neglected for many engineering calculations of this type.

The numerical values for the heat- and mass transfer coefficients may be obtained from the literature. Reference may be made to the work of Molsted et al,[2] and Johnstone and Singh[3] for grid packed towers. It is beyond the scope of this article to give a review of these data. However, it can be said that Molsted's data as obtained from ammonia absorption experiments are usually considered as low, due to liquid film resistance. On the other hand, Johnstone and Singh's coefficients are probably too high, due to the influence of entrance effects. It thus appears that there is a great need for more data on heat- and mass transfer coefficients in grid-packed towers.

It would greatly simplify the calculation and design of direct contact coolers if one could calculate an average total heat transfer coefficient, $h_{av}$, and an average temperature difference, $\Delta t_{av}$. Equation (2) would then read,

$$A = \frac{Q}{h_{av} \cdot \Delta t_{av}} \qquad (3)$$

It was recognized early that the logarithmic mean temperature difference calculated from the in- and outlet conditions in the tower is inadequate for the calculation of those coolers in which the total heat transfer coefficient, $h_t$, and the specific heat of the gas-vapor mixture are the subject of considerable variation.

When the entering gas-vapor mixture is saturated, the asumption is often made that the mixture remains saturated while being cooled. Then, it is very easy to calculate corresponding gas- and cooling water temperatures at several intermediate points of the cooler. This can be done by a simple heat balance, assuming adiabatic conditions in the tower, and accounting for the variation in the ratio $L/G_o$, due to condensation. The temperatures of the cooling water and the gas-vapor mixture so obtained can be plotted against the total heat transferred (see Figure 1).

Haug and Mason[4] have proposed to calculate the average temperature difference, $\Delta t_{av}$, from the area between the two curves in Figure 1.

Tymstra[5] has shown, however, that the temperature difference so obtained is not equal to the true average temperature difference, $\Delta t_{av}$, as required for the solution of Equation (3). Tymstra has then proposed to use the logarithmic mean temperature plus half of the arithmetic temperature difference of the in- and outlet conditions of the tower. It is known that this method gives better results in some cases. However, as there is no theoretical justification for this computation, the limits of its applicability can not be estimated. Moreover, neither Haug and Mason nor Tymstra have offered a method for the calculation of the average total heat transfer coefficient, $h_{av}$, enabling the solution of Equation (3).

Rosebaugh[6] has presented extensive experimental data for the total heat transfer coefficient, $h_{av}$, of a wood-grid packed tower in which saturated oil gas was cooled with cold sea water. Unfortunately, his data are based on the average temperature difference calculated by application of the method of Haug and Mason.[4]

The mechanism of simultaneous heat- and mass transfer in a scrubber-condenser for saturated gas-vapor mixtures has many points of similarity with that encountered in water cooling-towers. The method usually applied for the calculation and design of water cooling towers is known as the enthalpy or total heat design method, first proposed by Merkel in 1925.[7] This method gives accurate results only when the Lewis relation, $h_g/k_g = s$, is valid, and when the vapor concentrations involved are relatively small. The Lewis relation is approximately correct for the system air-water vapor, but may show great deviations for other gas-vapor mixtures. When the mole fraction of the vapor in the gas mixture is large, e.g. over 0.15, the enthalpy potential may become inaccurate in representing the driving forces in the tower.

Mizushina and Kotoo[8] have proposed to use a modified enthalpy for the design of cooler-condensers handling gas-vapor mixtures for which the Lewis relation does not hold. The same principle could be used for the design of direct contact gas-coolers. However, this procedure may become inaccurate in case of high partial vapor pressures or humidities, for the same reason as applies to Merkel's enthalpy method.

Another method for the calculation of scrubber-condensers has been proposed by Silver.[9] He has calculated the total heat transfer coefficient, $h_t$, by multiplication of the sensible heat transfer coefficient, $h_g$, by the quotient of the total heat capacity and the sensible heat capacity of the saturated gas-vapor mixture, or

$$h_t = h_g \cdot \left(\frac{dQ_t}{dQ_s}\right)_{eq.} \qquad (4)$$

For convenient computation, Silver has given a plot of $(dQ_t/dQ_s)_{eq.}$ against the temperature for coal gas. Values of $h_t$ are calculated at various intermediate points in the tower, taking $h_g$ as a constant. At the same intervals, values of the temperature difference, $(t_g - t_w)$, are calculated, e.g. from a plot as shown in Figure 1. The packing surface required for the tower is then obtained by a graphical or numerical integration of Equation (2).

The assumption that the heat transfer coefficient, $h_g$, is constant introduces an error in case of great variation in the gas mass velocity. Moreover, Equation (4) is an approximation only. From Equation (1), it can namely be seen that the total heat transfer coefficient, $h_t$, is equal to,

$$h_t = h_g \left\{ 1 + \frac{k_g \Delta p \lambda_w}{h_g \Delta t} \right\} \qquad (5)$$

or,

$$h_t = h_g \left(\frac{dQ_t}{dQ_s}\right) \qquad (6)$$

It can thus be concluded that Silver's equation, Equation (4), is correct when $(dQ_t/dQ_s) = (dQ_t/dQ_s)_{eq.}$ This will be the case when the saturated gas-vapor mixture follows the saturated curve, due to true heat- and mass transfer. In a recent publication, the author[10] has pointed out in some more detail under which conditions

a gas-vapor mixture subjected to simultaneous heat- and mass transfer will remain saturated or will show a tendency to supersaturation or superheating. In many practical cases, gas-vapor mixtures usually handled in industrial plants will show a tendency to supersaturation. Then, the gas-vapor mixture may follow the saturated curve also, but due to the effect of fog formation in the gaseous phase. Under those conditions, no conclusions can be drawn in respect to the ratio between heat- and mass transfer, or the ratio between heat- and total heat transfer coefficients, based on the fact that the gas-vapor mixture remains saturated.

Carey and Williamson[10] have tried to generalize Merkel's enthalpy design method. They use the enthalpy divided by the steam ratio as the driving force for total heat. The method involves the calculation of an average driving force from a plot of the enthalpy divided by the steam ratio against the total heat transferred. The two terminal driving forces plus the driving force at the point where half of the total heat has been transferred are then used for the determination of the true average driving force. This value can be computed from a diagram prepared by Stevens.[10] The diagram is based on the assumption that a plot of the driving force against the total heat transferred is a parabola. No theoretical justification for this assumption has been given, and moreover, the method does not provide for variation in the heat- and mass transfer coefficients in the tower due to variation in the gas mass velocity and the physical properties of the gas-vapor mixture.

Cairns[11] has presented an approximation method for the calculation of cooler-condensers. He calculates the total heat flux, $h_t(t_g - t_c)$, for the inlet and outlet of the tower and for the point where half of the total heat has been transferred. The calculation of the heat flux at the three points is done by application of the Colburn and Hougen method for the design of cooler-condensers,[12] taking into account proper variation in heat- and mass transfer coefficients in the condenser. The assumption is then made that a plot of heat flux against total heat transferred is a parabola. Then, if the heat flux is expressed in the form $h_t(t_g - t_c) = aQ^2 + bQ + c$, the three constants a, b, and c, can be calculated from the three values for the heat flux calculated, and Equation (2) can be solved by analytical integration, or by making use of the Stevens diagram.[10] The same method can be used for the calculation of direct contact coolers for hot saturated gas-vapor mixtures.

Cairns has found that the method gives accurate results for four out of five example calculations, but shows a deviation of —42 percent in another case. The author[1] has recently published design calculations for a cooler-condenser handling a saturated mixture of carbon dioxide and water vapor, and it was found that the application of Cairns' method resulted in a deviation of +27 percent, as compared with the Colburn-Hougen method. In the example that will be given in this article, it will be shown that the application of Cairns' approximation method results in an error of —27.5 percent. Although the heat- and mass transfer coefficients available for packed towers do not possess a very great accuracy, it is nevertheless felt that the application of approximation methods with unknown reliability would place the design calculations on a rather obscure basis.

It is therefore believed, that it would be better to calculate direct contact coolers for hot saturated gases by the proper solution of Equations (1) and (2). Corresponding values for the cooling water temperature and the gas temperature, $t_w$ and $t_g$, can be obtained from a simple heat balance, assuming adiabatic conditions in the tower, and taking into account the variation in the ratio of liquid- and gas flow, L/G, due to condensation of part of the vapor. Point to point values for the heat- and mass transfer coefficients can be obtained by application of methods available in the literature.

It is thus possible to calculate point to point values for the heat flux, $h_t(t_g - t_w)$, and the total heat transferred, Q. The packing area required can then be found by graphical integration of Equation (2). This is done by plotting the total heat transferred, Q, against values of $1/h_t(t_g - t_w)$. The area under the integration curve so obtained, must be equal to the packing area, A. The area can be measured or calculated by multiplication of small increments of Q with the average value of $1/h_t(t_g - t_w)$ of the increment.

It has been shown recently by the author[1] that the mass transfer coefficient can be eliminated from the design Equation (1), by the introduction of a factor $F' = (L_v/C_m) \cdot (Pr/Sc)^{2/3}$. The introduction of this group not only eliminates the point to point calculation of the mass transfer coefficient, $k_g$, but also reduces the number of physical constants that have to be calculated from point to point, and that are necessary for or connected with the calculation of $k_g$.

The Factor F′ shows little variation with the temperature for most saturated gas-vapor mixtures, and is a function of the physical properties of the gas-vapor mixture only. The gas mass transfer coefficient, $k_g$, on the other hand depends on those variables as the gas mass velocity, Reynolds number, tube diameter, etc. Therefore, it will be obvious that the elimination of the mass transfer coefficient and the introduction of the factor F′ will be of advantage when series of design calculations are to be made, involving variation in tower diameter, packing dimensions, gas and liquid flow rates, etc. Series of this kind are usually required for the determination of the most economical tower dimensions and flow conditions.

The principle of this method is suitable and convenient for the calculation and design of scrubber-condensers also. It is thus the purpose of the present article to show the application of this method in an example, and to compare the result with Cairns' approximation method. Before this is done the derivation of the simplified design equation for direct contact coolers will be given.

**Simplified Design Equation**—In Equation (5), we can introduce the Chilton and Colburn analogy of heat- and mass transfer,[14] or,

$$\frac{k_g}{h_g} = \frac{M_v}{M_m \, c \, p_{gf}} \cdot \left(\frac{Pr}{Sc}\right)^{2/3} \qquad (7)$$

This delivers,

$$h_t = h_g \left\{ 1 + \frac{M_v \lambda_w}{M_m \, c \, p_{gf}} \cdot \left(\frac{Pr}{Sc}\right)^{2/3} \cdot \frac{\Delta p}{\Delta t} \right\} \qquad (8)$$

After introduction of the approximation, $\lambda_w = \lambda_g$, which

is accurate enough for most engineering calculations, we can write,

$$h_t = h_g \left\{ 1 + \frac{F}{p_{gf}} \cdot \frac{\Delta p}{\Delta t} \right\} \quad (9)$$

where, $$F = \frac{M_v \lambda_g}{M_m c} \cdot \left( \frac{Pr}{Sc} \right)^{2/3} = \frac{k_g \lambda_g p_{gf}}{h_g} \quad (10)$$

As has been pointed out previously,[1] the value for $(Pr/Sc)^{2/3}$ may be based on the conditions in the main bulk of the gas-vapor stream, when the difference between the temperature of the cooling liquid and of the gas-vapor mixture is relatively small, so that $(T_f/T_g)^{2/3}$ is near to unity. We can then write,

$$F' = \frac{M_v \lambda_g}{M_m c} \cdot \left( \frac{Pr}{Sc} \right)^{2/3}_g \quad (11)$$

and $$h_t = h_g \left( 1 + \frac{F'}{p_{gf}} \cdot \frac{\Delta p}{\Delta t} \right) \quad (12)$$

It can be seen that the factor F′ has the dimension of a temperature differential. Its introduction in the design Equation (12) is convenient, because as the factor is a function of the gas temperature and the gas composition, its value can be calculated in advance for saturated gas-vapor mixtures.

For the design of direct contact coolers for saturated gases, it is most convenient to prepare a plot of F′ against temperature, for easy computation. Such a plot, as calculated for a saturated mixture of carbon dioxide and water vapor, has been shown in Figure 2. For most gas-vapor mixtures, the factor F′ shows little variation with the temperature, so that only a few points have to be calculated.

It will be obvious, that the total heat transfer coefficient, as expressed by Equation (12), is in terms of the heat transfer coefficient only, and that the mass transfer coefficient, $k_g$, has been eliminated. This is advantageous because point to point calculation of the mass transfer coefficient is no longer required. Also, the point to point calculation of the average molecular weight of the gas-vapor mixture, $M_m$, the density, $\rho$, and the diffusion coefficient, D, which are all required for the calculation of the mass transfer coefficient, and the Schmidt number, Sc, can be left out, once a plot of F′ vs. $t_g$ has been prepared. The introduction of the factor F′, and the elimination of the mass transfer coefficient, $k_g$, is of special interest when series of design calculations are to be made, involving variations in gas mass velocity, Reynolds number, and mass transfer coefficients.

In case of great differences between the gas- and liquid temperature, the quotient of the Prandtl- and Schmidt numbers, $(c\rho D_f/k_f)$ is dependent on the average gas film conditions. Neglecting the variation of $D_f/k_f$ with the gas composition, and assuming this ratio is proportional with the absolute temperature, we can write,

$$F = F' (T_f/T_g)^{2/3} \quad (13)$$

In those cases, the calculation of the Factor F by application of Equation (13) is convenient, and the total heat transfer coefficient, $h_t$, can be calculated with Equation (9).

When it may become necessary to correct the heat transfer coefficient, $h_g$, for the effect of the sensible heat of the diffusing vapors, the following equation for the total heat transfer coefficient, $h_t$, may be used,

$$h_t = h_g \left\{ \frac{a\, e^a}{(e^a - 1)} + \frac{F}{p_{gf}} \cdot \frac{\Delta p}{\Delta t} \right\} \quad (14)$$

For the derivation of this equation, reference is made to the author's previous publication.[1]

The equations derived thus far for the total heat transfer coefficient, $h_t$, are based on the Chilton-Colburn heat- and mass transfer analogy, and on the assumption that the surface available for heat- and mass transfer is equal. It has already been pointed out that the latter assumption is usually justified in case of wetted wall towers, and towers packed with wood grid or similar packing. In case of towers packed with Raschig rings, Berl saddles, etc., it may be necessary to introduce a correction factor for unequal surface for heat- and mass transfer. When the Chilton-Colburn analogy, as expressed by Equation (7), does not apply, any other correlation for the ratio between heat- and mass transfer may be substituted in Equation (5). Consequently, this will result in a somewhat different mathematical expression for the factor F.

**Example**—A direct contact cooling tower has to handle 3775 pounds per hour of carbon dioxide saturated with water vapor. This mixture enters at the bottom of the tower at 1 atmosphere pressure and 203 F., and leaves at the top of the tower at 95 F. Cooling water is sprayed from the top of the tower at 77 F., and leaves at the bottom at 199.4 F.

The tower has a square cross section and its dimensions are 3.92 feet x 3.92 feet. The tower is packed with grids, 6-inch high, 0.75-inch thick, and the clearance between the grids is 3 inches. The grids of each hurdle are set at right angles to each other. Each packed section of 3 feet is followed by an empty space of 1 foot, in order to facilitate redistribution of the liquid.

It is required to calculate the height of the packing.

**Solution**—The enthalpy of the saturated carbon dioxide at various intermediate points in the tower, has been calculated by taking the average specific heat of carbon dioxide and water vapor equal to 0.21 Btu per pound per °F. and 0.48 Btu per pound per °F., respectively, and the enthalpy is then,

$$i = 0.21\,(t_g - 32) + H\{0.48\,(t_g - 32) + 1071\}$$

The humidity, H, is equal to

$$H = \frac{p_v}{1 - p_v} \cdot \frac{18}{44}$$

In Table 1, the partial water vapor pressure, $p_v$, the humidity, H, and the enthalpy, i, have been listed at various temperatures, $t_g$.

The liquid-gas flow ratio, $L/G_o$, at the top of the tower can be calculated from,

$$(L + 2.033)\,(199.4 - 32) - L\,(77 - 32) = G_o\,(2407.23 - 39.70) \text{ or, } L/G_o = 16.563 \text{ lb/lb.}$$

The ratio $L/G_o$ at various intermediate points can then be obtained by adding to the ratio at the top, $L/G_o = 16.563$, the difference between the humidity of the gas at the point under consideration and the humidity of the leaving gas, H = 0.24 lb/lb.

Next, the temperature of the cooling water, $t_w$, can

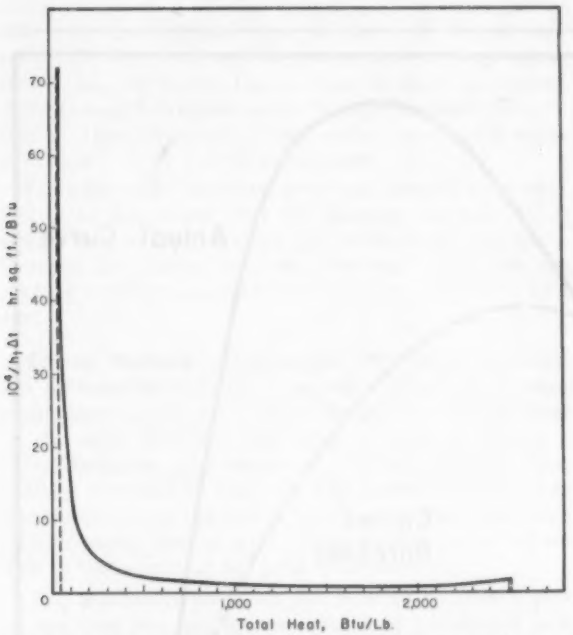


**FIGURE 3—Graphical integration for the determination of the total packing surface area required in the example.**

be calculated from a heat balance, assuming adiabatic conditions in the tower. The expression for the heat balance in this case is,

$$L\,(t_w - 32) - 16.563\,(77 - 32)\,G_o = G_o\,(i - 39.70)$$
$$\text{or, } (L/G_o)\,(t - 32) - 16.563\,(77 - 32) = i - 39.70$$

Intermediate values for the liquid-gas ratio, $L/G_o$, and the cooling water temperature, $t_w$, have been listed in Table 1, together with the corresponding values for the equilibrium partial water vapor pressure, $p_v$, and the heat- and mass transfer driving forces, $(t_g - t_w)$, and $(p_v - p_w)$, respectively.

**Heat Transfer Coefficient**—The calculation of the heat transfer coefficient, $h_g$, from point to point, has been carried out by making use of the correlation for grid packing presented by Johnstone and Singh.[3] These authors have carried out experiments in a tower packed with 1.67 to 4 feet of wood grids. The data are sometimes believed to be too high, due to entrance effects. However, in the tower under consideration here, where sets of packing three feet high are being followed by a free space, the correlation will probably be satisfactory. Johnstone and Singh's equation for big towers is,

$$j' = 0.035\left(\frac{d_e\,G'}{\mu}\right)^{-0.2} + \frac{d_e^{0.8}}{(d_e\,d_g)^{0.4}} \qquad (15)$$

$$\text{and, } h_g = \frac{j'\,c\,G'}{Pr^{2/3}} \qquad (16)$$

Since the void fraction of the grid packing is equal to $3/3.75 = 0.800$, the gas mass velocity, $G'$, based on the actual free cross section is,

$$G' = \frac{G_o\,(1 + H)}{(3.92)^2 \cdot 0.800}\ \text{lb./hr. sq. ft.}$$

where $G_o = 3775$ lb/hr.

The point to point values for the gas mass velocity, $G'$, the viscosity $\mu$, and the Reynolds number, $d_e\,G'/\mu$, and the transfer factor, $j'$, are shown in Table 2.

The viscosity of the gas-vapor mixture, $\mu$, has been calculated by addition of the viscosity of the components

**TABLE 1**
**Calculation of Driving Forces for Various Intermediate Points**

| $t_g$ F. | $p_v$ atm. | H lb/lb | i Btu/lb | $L/G_o$ | $t_w$ F. | $p_w$ atm. | $p_v - p_w$ atm. | $t_g - t_w$ F. |
|---|---|---|---|---|---|---|---|---|
| 203 | 0.8341 | 2.057 | 2407.23 | 18.596 | 199.4 | 0.7745 | 0.0596 | 3.6 |
| 202.1 | 0.8190 | 1.851 | 2168.62 | 18.390 | 188.3 | 0.6127 | 0.2063 | 13.8 |
| 201.2 | 0.8038 | 1.676 | 1966.84 | 18.215 | 178.7 | 0.4967 | 0.3071 | 22.5 |
| 200.3 | 0.7892 | 1.531 | 1798.85 | 18.070 | 170.6 | 0.4133 | 0.3759 | 29.7 |
| 199.4 | 0.7745 | 1.405 | 1652.60 | 17.944 | 163.4 | 0.3498 | 0.4247 | 36.0 |
| 197.6 | 0.7460 | 1.202 | 1417.39 | 17.741 | 151.65 | 0.2636 | 0.4824 | 45.95 |
| 194 | 0.6918 | 0.918 | 1088.87 | 17.457 | 134.75 | 0.1717 | 0.5201 | 59.25 |
| 185 | 0.5705 | 0.544 | 654.09 | 17.083 | 111.6 | 0.0909 | 0.4796 | 73.4 |
| 167 | 0.3804 | 0.251 | 313.60 | 16.690 | 92.7 | 0.0517 | 0.3287 | 74.3 |
| 149 | 0.2468 | 0.134 | 175.63 | 16.673 | 84.7 | 0.0404 | 0.2064 | 64.1 |
| 131 | 0.1553 | 0.075 | 104.93 | 16.614 | 80.8 | 0.0354 | 0.1199 | 50.2 |
| 113 | 0.0946 | 0.043 | 64.44 | 16.582 | 78.45 | 0.0328 | 0.0618 | 34.55 |
| 95 | 0.0555 | 0.024 | 39.70 | 16.563 | 77.0 | 0.0313 | 0.0242 | 18.0 |

**TABLE 2**
**Calculation of the Heat Transfer Coefficient**

| $t_g$ F. | $\mu$ lb./hr. ft. | $G'$ lb./hr. ft.$^2$ | $Re'$ | $j'$ | $c$ Btu/lb. F. | $Pr^{2/3}$ | $h_g$ Btu/hr. ft.$^2$ F. |
|---|---|---|---|---|---|---|---|
| 203 | 0.0334 | 940.0 | 7,040 | 0.01920 | 0.392 | 1.047 | 6.76 |
| 202.1 | 0.03355 | 876.7 | 6,535 | 0.01929 | 0.386 | 1.038 | 6.29 |
| 201.2 | 0.03365 | 823.3 | 6,120 | 0.01936 | 0.381 | 1.034 | 5.865 |
| 200.3 | 0.0338 | 780.0 | 5,760 | 0.01944 | 0.375 | 1.028 | 5.53 |
| 199.4 | 0.0340 | 740.6 | 5,450 | 0.01952 | 0.368 | 1.022 | 5.205 |
| 197.6 | 0.0345 | 678.3 | 4,915 | 0.01965 | 0.357 | 1.011 | 4.70 |
| 194 | 0.0348 | 590.0 | 4,240 | 0.01983 | 0.339 | 0.994 | 3.99 |
| 185 | 0.0359 | 475.3 | 3,313 | 0.02017 | 0.305 | 0.965 | 3.025 |
| 167 | 0.03725 | 385.7 | 2,588 | 0.02051 | 0.264 | 0.930 | 2.245 |
| 149 | 0.03785 | 349.7 | 2,308 | 0.02068 | 0.2415 | 0.913 | 1.915 |
| 131 | 0.03775 | 331.3 | 2,193 | 0.02075 | 0.2285 | 0.907 | 1.73 |
| 113 | 0.0373 | 321.0 | 2,150 | 0.02078 | 0.2205 | 0.903 | 1.63 |
| 95 | 0.0366 | 315.3 | 2,155 | 0.02078 | 0.216 | 0.904 | 1.565 |

**TABLE 3**
**Point to Point Calculation of Heat Flux**

| $t_g$ F. | $F'$ F. | $p_{sf}$ atm. | $h_i\,\Delta t$ eq. 12 Btu/hr.ft.$^2$ | $h_i\,\Delta t$ eq. 17 Btu/hr.ft.$^2$ | Percent Deviation |
|---|---|---|---|---|---|
| 203 | 2,506 | 0.1945 | 5,225 | 5,225 | 0.0 |
| 202.1 | 2,510 | 0.2715 | 12,085 | 7,855 | −35.0 |
| 201.2 | 2,515 | 0.3265 | 14,020 | 9,545 | −32.0 |
| 200.3 | 2,515 | 0.368 | 14,365 | 10,550 | −26.5 |
| 199.4 | 2,516 | 0.401 | 14,055 | 11,150 | −20.6 |
| 197.6 | 2,517 | 0.454 | 12,785 | 11,555 | − 9.5 |
| 194 | 2,538 | 0.5275 | 10,215 | 10,970 | + 7.2 |
| 185 | 2,569 | 0.640 | 6,045 | 8,140 | +34.8 |
| 167 | 2,619 | 0.774 | 2,665 | 4,285 | +60.8 |
| 149 | 2,669 | 0.854 | 1,361 | 2,320 | +70.4 |
| 131 | 2,718 | 0.9025 | 711 | 1,220 | +71.8 |
| 113 | 2,767 | 0.936 | 354 | 555 | +57.0 |
| 95 | 2,803 | 0.9575 | 139 | 139 | 0.0 |

**TABLE 4**
**Numerical Integration of Design Equation**

| $t_g$ F. | $10^4/h_i\,\Delta t$ hr. ft.$^2$/Btu | $\left(10^4/h_i\,\Delta t\right)_{av}$ hr. ft.$^2$/Btu | $\Delta q$ Btu/lb. | $\Delta A$ $G_o$ ft.$^2$/hr./lb. |
|---|---|---|---|---|
| 203 | 1.914 | | | |
| 202.1 | 0.828 | 1.371 | 238.61 | 0.03270 |
| 201.2 | 0.713 | 0.7705 | 201.78 | 0.01554 |
| 200.3 | 0.696 | 0.7045 | 166.84 | 0.01175 |
| 199.4 | 0.711 | 0.7035 | 147.40 | 0.01037 |
| 197.6 | 0.783 | 0.747 | 235.21 | 0.01757 |
| 194 | 0.978 | 0.8805 | 328.52 | 0.02893 |
| 185 | 1.655 | 1.3165 | 434.78 | 0.05715 |
| 167 | 3.75 | 2.7025 | 340.49 | 0.09200 |
| 149 | 7.35 | 5.550 | 137.97 | 0.07650 |
| 131 | 14.07 | 10.71 | 70.70 | 0.07575 |
| 113 | 28.25 | 21.16 | 40.49 | 0.08550 |
| 95 | 71.94 | 50.095 | 24.74 | 0.1240 |
| | | | Total... | 0.62776 |

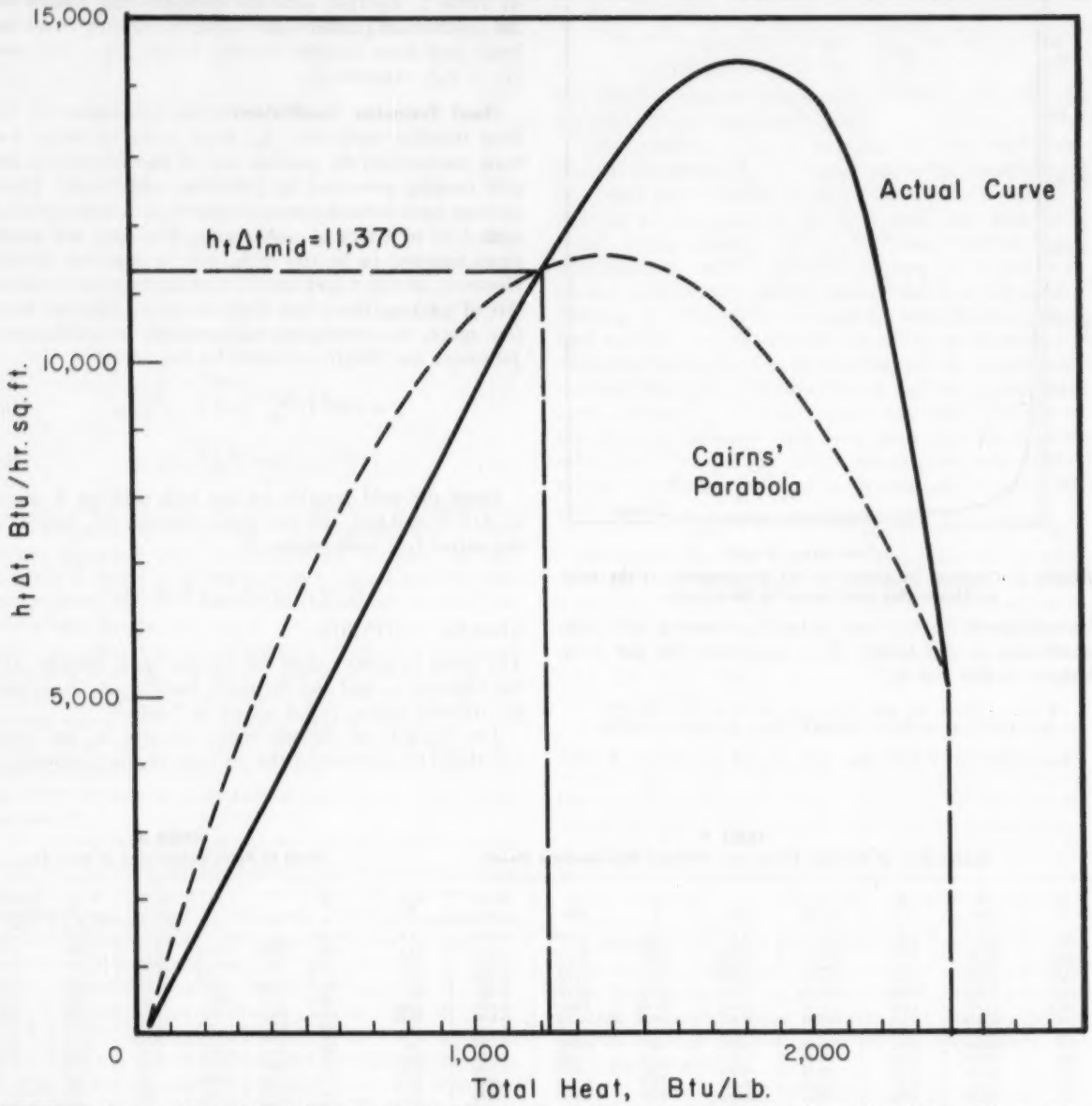


**FIGURE 4—A comparison of the heat flux versus the total heat transferred for the Cairns method and the actual conditions of the example.**

multiplied by the mole fractions. Although this procedure is not quite correct, the error involved is usually small for binary mixtures with components which molecular weights are not too far different. The thermal conductivity, k, of the saturated carbon dioxide-water vapor mixture has been calculated in the same way.

The specific heat of the saturated gas-vapor mixture, c, has been calculated by the equation,

$$c = \frac{0.21 + 0.48\,H}{1 + H}$$

Point to point values for the gas viscosity, $\mu$, the two-third power of the Prandtl number, $c\mu/k$, and the specific heat, c, and the heat transfer coefficient, $h_g$, are given in Table 2.

In Table 3, the factor F′, and the logarithmic mean pressure of the non-condensing gas are shown. For the physical constants required for the calculation of the factor F′, reference may be made to the author's recent publication.[1] Table 3 further shows the point to point values for the total heat flux, $h_t\Delta t$, calculated by application of Equation (12).

**Packing Height**—In Table 4, the heat flux, $h_t\Delta t$, and the reciprocal heat flux, $1/h_t\Delta t$, are given. In Figure 3, the reciprocal heat flux has been plotted against the total heat per pound of dry gas, i. The area under the curve so obtained is equal to $A/G_o$, in accordance with Equation (2), where $dQ = -G_o di$. The area under the integration curve for Equation (2), Figure 3, can be measured or calculated by multiplication of small increments in total heat transferred, $\Delta q$, by the average value

of the reciprocal heat flux, $(1/h_t\Delta t)_{av}$. The latter procedure has been followed here. In Table 4, the average reciprocal heat flux and the increments of heat transferred, $\Delta q$, are listed. The product of these two values delivers small increments of $A/G_o$, and the total $A/G_o = 0.6278$. Thus, the total packing surface required is equal to $0.6278 \times 3775 = 2367$ square feet.

From the grid dimensions given and the grid clearance, it can be calculated that the packing contains 101.4 square feet per foot. Taking into account the free space between the packed sections, the total height of the packing required is equal to $2367/(101.4 \times 0.75) = 31.1$ feet.

**Cairns' Method**—The example given has been worked out by calculating a few more intermediate points than would normally be required for the solution of a problem of this type. This has been done in order to obtain a better basis for the comparison with the approximation method proposed by Cairns.[11] The method requires only the calculation of the heat flux at the entrance and outlet of the tower, and at a one intermediate point, where half of the total heat has been transferred.

The method is based on the assumption that a plot of the heat flux against the total heat transferred is a parabola. No theoretical justification for this assumption has been presented, however. It is therefore difficult to estimate the magnitude of eventual deviations. In the example given above, the heat flux at the bottom, the top, and another point of the tower where half of the total heat has been transferred, is equal to,

$$h_t \Delta t_1 = 5{,}225$$
$$h_t \Delta t_2 = 139$$
$$h_t \Delta t_{mid} = 11{,}370$$

Assuming that a plot of the heat flux, $h_t\Delta t$, versus the total heat transferred, q, is a parabola with the axis parallel to the heat flux ordinate, the following equation will hold,

$$h_t \Delta t = a\,q^2 + b\,q + c \qquad (17)$$

The three constants, a, b, and c, are respectively,

$$a = 2\,(h_t \Delta t_2 + h_t \Delta t_1 - 2\,h_t \Delta t_{mid})/q^2$$
$$b = (h_t \Delta t_1 - h_t \Delta t_2)/q$$
$$c = h_t \Delta t_{mid}$$

In this example,

$$a = -0.006200$$
$$b = 2.1483$$
$$c = 11{,}370$$

The value for $h_t\Delta t_{mid} = 11{,}370$ has been obtained from a plot of the heat flux against the total heat transferred, see Figure 4.

When the equation for the heat flux, $h_t\Delta t$, is substituted in Equation (2),

$$A = \int_{-q/2}^{+q/2} dA = \int_{-q/2}^{+q/2} \frac{G_o\,dq}{aq^2 + bq + c} \qquad (18)$$

Integration of this equation, and rearranging delivers, for $b^2 > 4ac$

$$A = \frac{G_o}{\sqrt{b^2 - 4ac}} \cdot \ln \left[ \frac{aq + b - \sqrt{b^2 - 4ac}}{aq + b + \sqrt{b^2 - 4ac}} \right]_{-q}^{+q} \qquad (19)$$

In this example, for $q = 2367.53$ Btu's per pound

$$A = 3775 \times 0.455 = 1718 \text{ square feet.}$$

The result is 649 square feet in error, or —27.5 percent.

In Table 3, point to point values of the heat flux calculated by application of Equation (17) are given, together with the percent deviation as compared with the heat flux calculated with Equation (12). It can be seen that the deviations range between +35.0 percent and —71.8 percent.

The data have been plotted in Figure 4. It can be concluded that the actual heat flux curve shows considerable deviation from the parabola represented by Equation (17), especially because the heat flux curve's axis is not parallel with the heat flux ordinate. It can further be seen that the actual curve shows a small deflection at the top of the tower where the heat flux is smallest.

## NOMENCLATURE

| | |
|---|---|
| A | Surface, sq. ft. |
| a | $k_g\,\Delta p\,c_{pv}/h_g$, dimensionless (equation 14). |
| a, b, c | Constants. |
| $C_m$ | Heat capacity of gas-vapor mixture at constant pressure, Btu/lb. mole F. |
| C, $c_{pv}$ | Heat capacity of gas-vapor mixture, and vapor, respectively, at constant pressure, Btu/lb. F. |
| D | Diffusion coefficient, ft.²/hr. |
| $d_g$, $d_s$, $d_t$ | Dimensions of wood grid, respectively height, clearance between grids, and thickness, inch. |
| F, F′ | $(L_v/M_m)\,(Pr/Sc)^{2/3}$, see Equations (10) and (11), F. |
| $G_o$ | Flow rate of vapor-free gas, lb./hr. |
| G′ | Gas mass velocity, lb./hr. sq. ft. of free cross-section. |
| H | Humidity, lb./lb. |
| $h_{av}$ | Average gas-film heat transfer coefficient, Btu/hr. sq. ft. F. |
| $h_g$ | Gas-film heat transfer coefficient, Btu/hr. sq. ft. F. |
| $h_t$ | Gas-film total heat transfer coefficient, Btu/hr. sq. ft. F. |
| i | Enthalpy of gas-vapor mixture, Btu/lb. of vapor-free gas. |
| j′ | Gas-film transfer coefficient, dimensionless. |
| k | Heat conductivity of gas-vapor mixture, Btu/hr. ft. F. |
| $k_g$ | Gas-film mass transfer coefficient, lb./hr. sq. ft. atm. |
| $k_z$ | Gas-film mass transfer coefficient, lb./hr. sq. ft. per unit of humidity. |
| L | Flow rate of liquid, lb./hr. |
| $L_v$ | Latent heat of condensation, Btu/lb. mole. |
| $M_v$ | Molecular weight of vapor, lb./lb. mole. |
| $M_m$ | Average molecular weight of gas-vapor mixture, lb./lb. mole. |
| P | Total pressure, atm. |
| Pr | Prandtl number, $c\mu/k$, dimensionless. |
| $p_v$ | Partial vapor pressure in gas-vapor mixture, atm. |
| $p_w$ | Partial vapor pressure at gas-liquid interface, atm. |
| $p_{gf}$ | Logarithmic mean partial pressure of the non-condensing gases in the gas-film, atm. |
| $\Delta p$ | Driving force for mass transfer, $p_v - p_w$, atm. |
| Q | Total heat transferred, Btu/hr. |
| $Q_s$ | Rate of sensible heat transfer, Btu/hr. |
| $Q_t$ | Rate of total heat transfer, Btu/hr. |
| q | Total heat transferred, Btu/lb. vapor-free gas. |
| Re′ | Reynolds' number, $d_sG'/\mu$, dimensionless. |
| Sc | Schmidt number, $\mu/\rho$ D, dimensionless |
| s | Humid heat capacity of gas-vapor mixture, Btu/F. per lb. of vapor-free gas. |
| $T_f$ | Average absolute temperature in gas-film, R. |
| $T_g$ | Absolute temperature of gas-vapor mixture, R. |
| $t_g$, $t_w$ | Temperature of gas-vapor mixture, and of cooling liquid, respectively, F. |
| $\Delta t$ | Driving force for heat transfer, $t_g - t_w$, F. |
| $\Delta t_{av}$ | Average driving force for total heat transfer, F. |
| V | Packing volume or tower volume, cu. ft. |
| $\mu$ | Viscosity of gas-vapor mixture, lb./hr. ft. |
| $\lambda$ | Latent heat of condensation, Btu/lb. |
| $\rho$ | Density of gas-vapor mixture, lb./cu. ft. |

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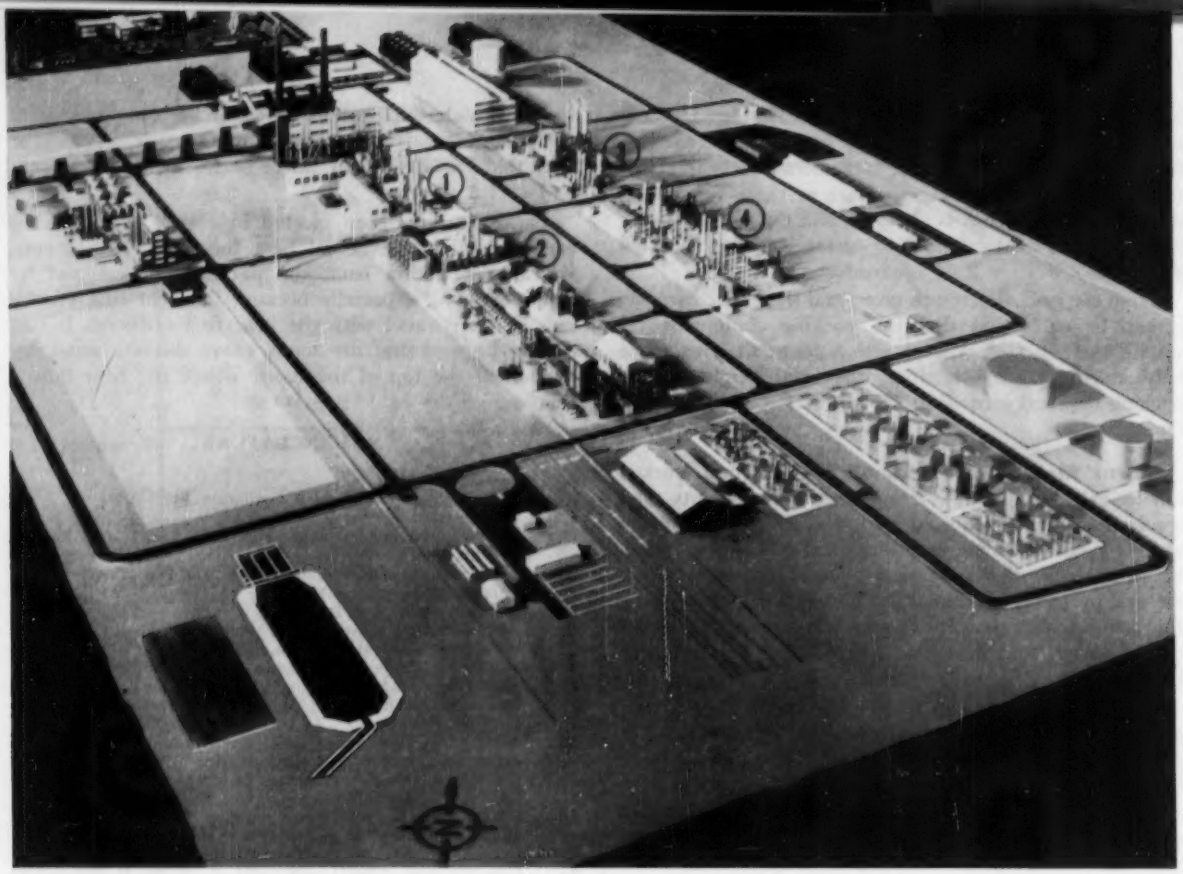



This model shows four of the principal units of the Sasol project: (1) the gasification and gas purification plants, (2) the gas reforming plant, (3) the Synthol plant, and (4) the hydrocarbon recovery, catalytic polymerization, and chemicals recovery sections.

# Coal Beats Oil Here

**In South Africa, Sasol plant produces chemicals and fuels from coal via Fischer Tropsch reaction. Here's how the units were designed, started up and operated.**

**W. B. Johnson**
The M. W. Kellogg Company
New York City

THE WORLD'S LARGEST oil-from-coal plant is now producing motor gasoline steadily for the automobiles of South Africa. This huge undertaking involved the cooperation of a large number of companies spread over three continents and is a testimonial to the farsightedness of the South African people.

SASOL, South African Coal Oil and Gas Corporation Ltd., is located in the Orange Free State approximately 50 miles south of the city of Johannesburg along the Vaal River. This river is the dividing line between the Transvaal and the Orange Free State. The surrounding country is typical high veld and is at an elevation of approximately 5000 feet. Durban, the nearest coastal seaport, is about 400 miles away. Major freight transportation from the coast to Johannesburg is supplied by the South African railways, a government owned railway system, while the majority of passenger traffic is by automobiles or bus on hard top and dirt roads.

The remoteness from the coast of the largest gasoline consuming area in the country is of course an important factor in the economics of

the oil-from-coal plant in this country but in addition there are large low grade coal deposits which are particularly adaptable to modern mechanical mining methods and thus can be mined at relatively low costs (approximately 75 cents per ton).

The Sasol plant site is ranch land and is about five miles from the Vaal River, the only source of water in the area. There were no living accommodations at the site and the nearest town, Vander Bijl Park, was across the river, seven miles away. Transportation across the river was by a mule-drawn two-car ferry called a "Pont."

This synthetic fuel plant is a new type of refinery. It consists of a large number of complicated process units which had to be tied together to produce the complex whole. The end result is a function of the proper performance of each of these parts.

The primary feed is a South African coal having the following approximate analysis:

| | Percent |
|---|---|
| Moisture | 6- 8 |
| Ash | 25-30 |
| Volatile Matter | 20-25 |
| Fixed Carbon | 40-45 |
| Calorific Value (LHV) | 8,000 Btu/lb. |

The process consists essentially of the gasification of the coal by steam and oxygen to CO and $H_2$ which are in turn reacted to form hydrocarbon and oxygenated chemicals. These products are subsequently refined for the market.

The normal design coal requirements are:

Power Plant—2350 Tons (US)/day
Gasification—3050 Tons /day
Total 5400 Tons /day

The plant was designed to produce the following products:

| From Gasification— | | |
|---|---|---|
| Ammonium Sulfate | 110 | tons/day |
| Crude Phenols | 96 | Bbl/day |
| Hydrogenated Naphtha | 105 | Bbl/day |
| Benzol | 59.5 | Bbl/day |
| Denaturing Benzol | 92.5 | Bbl/day |
| Toluol | 19.5 | Bbl/day |
| Heavy Naphtha | 7.0 | Bbl/day |
| Creosotes | 105.0 | Bbl/day |
| Tar (Pitch) | 1010.0 | Lbs/Hr. |

| From Kellogg Synthesis*— | Bbl/day |
|---|---|
| LPG | 24 |
| Gasoline (92 CFRR Clear) | 3661 |
| Diesel Oil | 142 |
| Waxy Oil | 46 |
| Methanol | 14.5 |
| Ethanol (Crude) | 12.0 |
| Ethanol | 302.0 |
| Methyl Ethyl Ketone | 21.8 |
| Acetone | 15.6 |

* Includes small amount of $C_3$ and $C_4$'s for Cat. Poly and Chemicals from Arge Synthesis Unit.

| From Arge Synthesis— | Bbl/day |
|---|---|
| Gasoline | 414.0 |
| Kerosine | 46.2 |
| Diesel Oil | 224.0 |
| Fuel Oil | 88.6 |
| Soft Wax | 24.5 |
| Medium Wax | 66.9 |
| Hard Wax | 156.5 |

The refinery is divided into nineteen sections as follows:

1. Water Treating, Steam and Power Generation
2. Oxygen Production and Compression plus Plant Air and Inert Gas Supply
3. Coal Gasification
4. Gas Purification
5. Gas Reforming and $CO_2$ Removal
6. Synthesis Catalyst Manufacture and Hydrogen Production
7. Kellogg Synthesis
8. Oil Product Treating and Recovery
9. Catalytic Polymerization
10. Chemical Recovery
11. Crude Phenol Recovery
12. Ammonium Sulfate
13. Naphtha Hydrogenation and Tar Distillation
14. Arge Synthesis
15. Arge Synthesis Product Recovery
16. Central Cooling Water System
17. Ash Handling
18. Product Tankage and Handling
19. Waste Disposal

**Organization**—In 1951 The M. W. Kellogg Company was awarded the over-all contract to design and build an oil-from-coal plant to produce as the major product motor gasoline. Kellogg was to act as a consultant and adviser in Sasol's behalf with respect to the subcontracting of certain sections of the plant. These sections included the Power Plant, Coal Gasification Unit, Gas Purification Unit, and Oxygen Plant. Sasol was assisted in issuing the initial inquiries for quotation, analyzing the proposals, checking pilot plant test data when operating with South African coal samples, writing of specifications and concluding of the contracts. Kellogg continued its function as adviser and engineering coordinator after these contracts were let. All construction work within the refinery was carried out under the supervision of Kellogg construction personnel.

Soon after Sasol awarded the contract it received a further appropriation from the South African Parliament to include a German "Arge" Synthesis Unit (Ruhrchemie-Lurgi) in the over-all project. This unit was planned to produce predominantly diesel oils and waxes amounting to about one third of the total refinery liquid production. All gas making facilities and refinery utilities were increased over the original proposal to accommodate the increased synthesis capacity. Certain modifications in the Gasification and Gas Purification Units were made in addition to an increase in capacity to permit adjustments in gas composition for the two different Synthesis Reactor systems. Unreacted gases from the Arge Synthesis as well as a chemical stream and light hydrocarbon stream for final recovery were returned to the Kellogg process units for further processing. In the case of the Arge Synthesis Unit Kellogg again acted as an engineering coordinator, purchased U. S. equipment for the unit, and did the erection work but assumed no process or engineering responsibility. The Arge Synthesis Process will not be discussed in this article.

**Power Plant**—Lump coal is transported on belt conveyors from the highly mechanized underground mine about 1½ miles to the refinery. It either passes to large storage bunkers which can hold approximately 10 days supply or directly to a crushing and screening plant which reduces all coal lumps to 2-inch size or less. The coal is separated here. All the fines up to about ½-inch are transported, again by belt conveyor, to storage bunkers over the boilers while the larger sizes are transported by belt conveyor to bucket conveyors for distribution to the Gasification Section.

Four powdered fuel boilers, outside type, were installed with a capacity per boiler of 360,000 pounds per hour of 550 psig, 820 F. steam. Normal design steam consumption (500

psig refinery steam) is slightly over one million pounds per hour so three boilers are in operation with the fourth boiler as standby. The boilers were designed to burn oil and refinery gas as well as powdered coal. Oil is used for start-up and emergency and refinery gas is used when gas must be wasted, either during start-up or during periods of operating difficulties in the liquid producing units or gas purification unit.

Electric power for the mine, refinery and town of Sasolburg is generated in the refinery Power Plant by two turbo-generators plus one standby each rated for normal design at 13,500 KW at 11,000 volts. This power is transformed to 3300 volts for distribution to the main electric substations in the refinery and for driving motors rated at 100 KW or greater. The turbines are designed to operate on 500 psig steam only or on a combination of high pressure and 35 psig steam. These turbines consume all excess low pressure steam to maintain the refinery in steam balance. All major steam drivers throughout the refinery are of the condensing type in order to keep water make-up to a minimum. River water is a very scarce commodity in the Union of South Africa.

Boiler make-up water from the Vaal River enters two large concrete settling basins or reservoirs. The main purpose of the reservoirs is to store river water during periods of low dissolved solids concentration for blending when the solids in the water rapidly rise. This occurs when the gold mine dumps on the Reef start draining into the river at the beginning of the rainy season. Of course, the reservoirs also serve as emergency standby for the river water pumping station and for fire protection.

The make-up water is treated in hot lime vats and is then passed through ion exchange treaters before being combined with recovered steam condensate for deaeration. Boiler feed water is deaerated by heating the water to 230 F. Most of this heat is supplied at low level heat from the Kellogg Synthesis overhead cooling system while the remainder is supplied by flashing low pressure steam.

The power plant started in the latter part of 1954 but it was the late spring of 1955 before reliable operation was attained. The delays were due primarily to inexperience in operating and maintenance as well as minor equipment failures.

**Meet the Author**

WILLIAM B. JOHNSON graduated from Princeton University in 1937 with a B.A. degree in chemistry and since that time has worked continuously for The M. W. Kellogg Company as research engineer, process engineer, and project engineer. In his present capacity as manager of the Synthol division, Johnson is in charge of all technical phases and much of the development of the synthesis plant in South Africa.

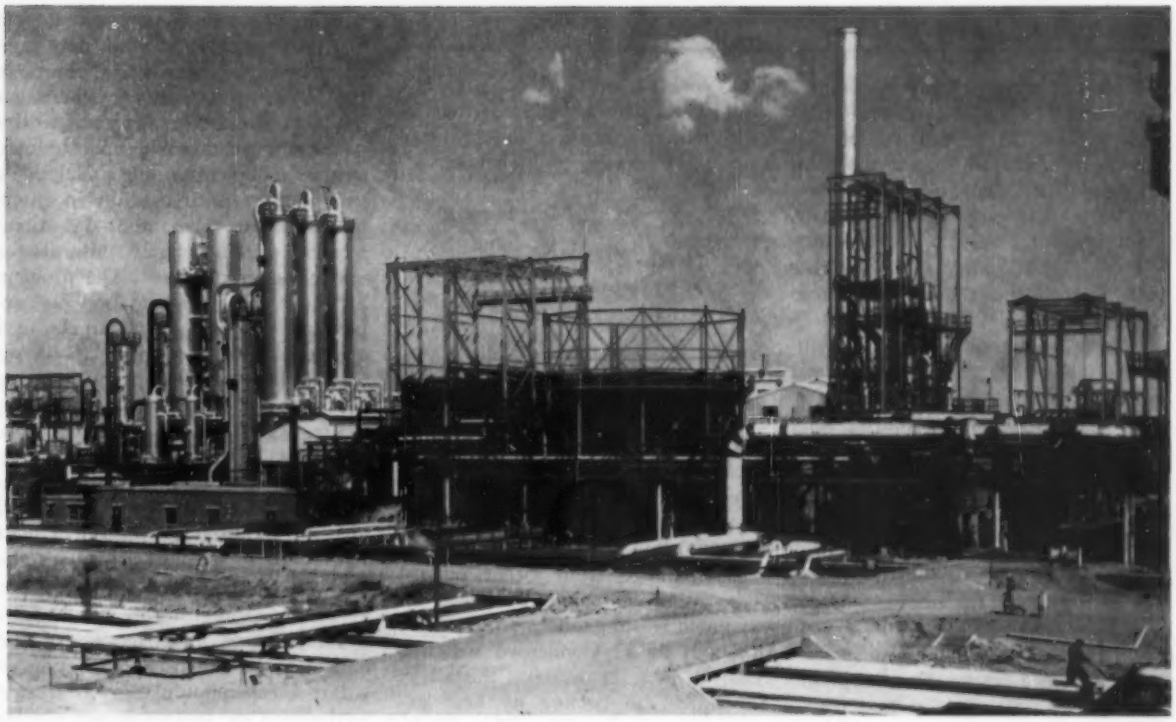
**Oxygen Plant**—Normal design requirements for 98 percent pure oxygen in the refinery are approximately 1500 tons per day but the total installed capacity is 1800 tons per day. This oxygen is supplied from six German Linde air fractionation units each rated at 300 tons per day of 98 percent pure oxygen. Each unit was completely fabricated, erected and disassembled in Germany prior to shipment. Each Linde box has a turbine driven air blower which compresses 30,500 SCFM of air to approximately 60 psig. Oxygen from each unit is led to a common header and the whole system floats on a large gasholder with about 10 minutes holding time at full capacity. The boxes are operated to maintain the quantity of oxygen in the holder as demand changes. Two turbine-driven compressors plus one spare take suction from the holder and compress the oxygen to 430 psig. These compressors were specially designed for the service with a number of safety features incorporated into the design. Special cleaning procedures were used throughout the entire oxygen system before initial operation.

In addition to the oxygen produced in this unit a 99.8 percent pure nitrogen stream is produced amounting to approximately 600,000 SCFH for use as inert gas throughout the refinery. This gas is compressed to 40 psig in the oxygen plant before distribution. Also located in the oxygen plant building are the service air supply system (100 psig) and the refinery instrument air driers.

The oxygen plant building is a steel building with corrugated asbestos roof and sides and consists of two main bays, one bay housing the Linde boxes with an electric service traveling crane overhead and the other the compressors and controls on the second floor and surface condensers on the ground floor.

Operation of the first Linde box started in the early part of 1955. Since then all units have proved to be very reliable and easily operated. They reached design capacity and product purity from the start and have even operated considerably over design capacity. The only difficulty of any significance in the operation of these units was a fire in one of the oxygen compressors in June of 1955 after the compressor had been in operation for several weeks. Of course all operations ceased in the refinery at this time for a complete investigation of the causes for this mishap. Some alterations and additional safety features were added to the two remaining compressors and since that time no further problems in this plant have arisen.

**Gasification Unit**—There are a total of nine Lurgi pressure coal gasifiers. At design conditions only eight gasifiers are required; the ninth is a standby. Each gasifier is designed to operate at high pressure and produce 837,000 SCFH of raw gas. The $H_2/CO$ ratio may be varied over the range of 2:1 to about 2.5:1 with South African coal by changing the ratio of steam to oxygen in the feed. Lower ratios which are required for the German (Arge) Synthesis are attained by substituting recycle $CO_2$ for steam. A typical analysis of the



**The gas purification section (right) and Rectisol unit (left) with a tar handling section in the foreground. Also in the foreground are a gas holder, connecting with the gasification unit, a compressor house and utility lines.**

raw gas at Sasol for the Kellogg Synthesis without $CO_2$ recycle is:

| | Mol. Percent |
|---|---|
| $N_2$ | 1.0 |
| $H_2$ | 39.3 |
| CO | 18.7 |
| $CO_2$ | 31.0 |
| $CH_4$ | 10.0 |
| | 100.0 |

The gasifier proper is a steel pressure shell surrounded by a jacket where some of the process steam is generated. Inside the gasifier there is a coal distributor at the top and a water cooled grate at the bottom which are joined together by a shaft extending the length of the shell. This combined internal mechanism is rotated by an electric motor and gears which are located outside the pressure shell. The gasifiers, 14 feet in diameter and 30 feet high, are very much larger than any previously built.

Coal is fed to the top of the gasifier through a hydraulically operated cone presure valve from a lock hopper and ash is removed at the bottom of the gasifier by a similar arrangement. Steam and oxygen are introduced to the combustion zone through the rotating grate at the bottom. Temperatures in the bottom of the gasifier reach a maximum of about 1800 F but are definitely controlled by the relative quantities of steam and oxygen to maintain these temperatures below the fusion point of the ash. The temperatures leaving the top of the gasifier are around 700-800 F so that the top of the coal bed is really a precoking section.

Lurgi pressure gasifiers are essential continuous gas producers. Periodically, however, the grate must be stopped for ash discharge. In spite of this fact there are surprisingly small fluctuations in feed composition and production when multiple units are on the line.

The overhead gases from the gasifier are scrubbed and then cooled in waste heat boilers which generate 40 psig steam for use in the refinery. The gases are finally cooled in water coolers.

The condensed liquid is flashed through cyclones and separated into two phases. The water phase is processed in the phenol and ammonium sulfate plants. The oil phase is hydrogenated and then distilled into various saleable fractions.

Included in the gasification plant is a gas holder for receiving released gas from the depressuring of the coal lock hoppers. There is also a gas fired furnace for superheating 40 psig steam from the waste heat boilers. Facilities for recycling $CO_2$ to the gasifiers when making low ratio gas are also in this section of the plant.

The gasifiers started preliminary operations during early 1955. With some mechanical alterations and after a period for gaining experience in operation and maintenance these units demonstrated their operability. It is still too early to ascertain their true stream efficiency but this has been improving steadily.

**Phenol Extraction and Ammonium Sulfate Units**—Waste water from the gasification unit passes into two large sludge separator tanks where entrained tars and oil sludge are separated out. It then goes to a holding tank from which it is pumped through sand filters for final removal of entrained matter and on to a gas saturator where waste gas from the unit, containing largely $CO_2$, is used to neutralize ammonia in the water. After neutralization the bulk of the

phenols are removed by extraction in multi-stage horizontal extractors with butyl acetate. Final removal of the phenols is carried out by stream stripping. The concentration of oxygenates in the water at this stage is about 30 ppm.

Ammonia is removed from the waste water after phenol extraction by steam stripping. The concentrated ammoniacal solution is contacted with sulfuric acid in large lead lined vats and the resulting ammonium sulfate crystals are dried and stored for sale as fertilizer.

**Gas Purification Unit** — The gas purification unit is a combined Lurgi-Linde process. At the time the primary contract was awarded the process was still in its infancy. Only laboratory bench scale work had been completed to obtain equilibrium data. Lurgi erected a large scale pilot plant in the early part of 1951 and commenced operations using as feed the product gas from their pilot gasifier which was then experimenting with South African coal samples. The data from these tests runs formed the basis for design of the commercial plant. The scaling up of the pilot plant proved to be a masterful job for with only slight modifications to the large unit and after gaining some operating experience the operability and success in removing impurities from the raw gas has been clearly demonstrated. What formerly required a number of complicated processes is now done in one very simple and easily operated unit.

In this unit the temperature of the gas is reduced by heat exchange and refrigeration to approximately —60 F. In the purification process the impurities are removed by solvent extraction with methanol at reduced temperatures. Essentially all sulphur compounds, gums and resin formers are removed and $CO_2$ is reduced to approximately 1.5 percent. Parallel purification systems were installed to permit simultaneous cleaning of the gas for the Kellogg and Arge Synthesis Systems. When the plant is operating at full capacity approximately two-thirds of the pure gas of the desired composition passes directly to the Arge Synthesis Unit.

In the gas purification unit hydrocarbons, gums and resin formers, HCN, organic sulfur compounds, $H_2S$ and $CO_2$ are removed from the raw gas. After purification the gas contains the following components:

| | Mole Percent |
|---|---|
| $N_2$ | 1.4 |
| $H_2$ | 56.1 |
| CO | 26.7 |
| $CO_2$ | 1.5 |
| $CH_4$ | 14.3 |
| | 100.0 |

Raw gas from the gasification unit passes through spray cyclones prior to entering the gas purification unit where any fine traces of dust or tar are removed. It is then cooled in a heat exchange train either against evaporating ammonia, pure gas, or expanded waste gas to a temperature of about 35 F. Condensed water is removed in a separator at this stage. Subsequent to cooling by heat exchange the gas enters the first scrubber tower where it is washed with a counter-current stream of methanol. Here higher boiling constituents in the gas together with absorbed lower boiling components are removed. The gas then passes on to the main scrubber tower where it is washed with freshly regenerated methanol to remove the remaining quantities of $CO_2$, $H_2S$ and COS.

Methanol is regenerated by flashing at a series of pressures down to subatmospheric pressure. This flashing also provides auto-refrigeration for the unit. The bulk of the waste gas is finally disposed of by passing it up the stacks of the main refinery boilers. Final regeneration of the methanol is by distillation.

To minimize methanol losses, the waste gas streams are cooled against cold methanol or liquid $CO_2$ prior to disposal.

The gas preparation steps described above have prepared the gas for entrance to the Kellogg units. These consist of the pressure gas reforming section, the Kellogg Synthesis section and the various product recovery sections.

**Gas Reforming Section**—The gasification product is fed to the reforming section where light hydrocarbons contained therein are converted to CO and $H_2$ for synthesis.

Prior to the Sasol contract, a great deal of experimental work and engineering of gas reforming plants to convert natural gas to synthesis gas had been done. The approach to this problem was along two separate lines, steam methane reforming at relatively low pressure with catalyst in externally heated tubes and the direct oxygen combustion of natural gas under higher pressures. The problem at Sasol was similar to previous experience but differed in that the feed composition and quantity to be reformed could be extremely variable depending upon operating conditions within the over-all plant. It was, therefore necessary to develop a process which could be readily operable at varying conditions and still give the required conversion of light hydrocarbons to synthesis gas at the refinery synthesis gas operating pressure.

Immediately after signing of the contract, the design and erection of a large scale pilot plant was started at Jersey City to reform gas similar in composition to that expected in the commercial unit. It was decided that this design would involve a combination of oxygen and steam reforming at an elevated operating pressure. Preliminary experiments indicated that the success of such a process depended upon a catalyst which could withstand the temperatures required for conversion of hydrocarbons at elevated pressure. A research program was started to test commercial catalyst under the required operating conditions. Pilot plant operations continued throughout 1952. The commercial unit design was established on the basis of the results from this unit.

In the final design the mixed gases are preheated in high temperature heat exchangers and combined with oxygen and steam in special mixing nozzles before passing through a catalyst bed. Temperatures at the top of the bed are approximately 2000 F. The gas leaving the catalyst reforming chamber contains the correct proportions of active components for the Kellogg Synthesis. This gas is cooled in waste heat boilers which generate the process stream requirements for the unit.

Proportioning of the gas and oxygen streams at the mixing nozzles is by ratio control with additional safety

instruments should there be any failure of the ratio controllers. Continuous recording gas analyzers of the infra-red and thermal conductivity types are installed on the feed and product streams. Similar instruments are located in the gas purification unit in order to assist the operators to maintain the desired $H_2$:CO ratio for both synthesis units.

The first commercial plant operations started about the middle of 1955. From a process and operating standpoint the unit performed very well; however, there were some mechanical problems which had to be ironed out before steady operating conditions were attained. These were primarily minor modifications to the steam, oxygen and gas mixing nozzles, some changes to the high temperature internal lining of the catalytic reforming chambers, and a different procedure for installing catalyst. Since the latter part of 1955 this unit has definitely established its operability at design conditions and has also demonstrated its flexibility on many occasions. The conversion of hydrocarbons to synthesis gas has always reached equilibrium concentrations with no traces of carbon formation.

**Catalyst Manufacture and Hydrogen Production**—Synthesis catalyst is manufactured from iron ore in a semi-continuous process. The ore is received from railway cars and is mechanically transported, dried, crushed, screened and stored in bins prior to fusion. A specially designed powder metering device was installed to assure a perfectly proportioned continuous feed to the furnace. The molten material is cooled, crushed to the desired particle size and conveyed to intermediate storage vessels. Catalyst is reduced batchwise.

Hydrogen, for catalyst reduction and hydrogenation of various liquid products within the refinery is generated in a conventional steam-iron process unit using raw synthesis gas from the gasification unit for regeneration of the iron bed. The rated output of 99.7 percent pure hydrogen for this unit is 360,000 SCFD.

**Kellogg Synthesis Unit**—Initial U. S. interest in Fischer Tropsch synthesis lay in the possible use of the process for conversion of waste natural gas to saleable liquid products. At about the same time extensive research was being carried out in Germany for the purpose of converting coal to liquid products. A few commerical units had already been erected using water gas sets for generating synthesis gas from coke. The synthesis units were operated at low pressure in fixed bed reactors with cobalt catalyst. The liquid products were essentially straight chain saturated hydrocarbons. Heat removal was difficult and required extensive and costly cooling surface. Kellogg began research on this process at its Jersey City Research Center in 1937.

Early investigations were at high pressures with iron catalyst. It was found that under these conditions a more unsaturated hydrocarbon and a gasoline product with a higher motor octane rating were produced.

Two large pilot plants were built to gain commercial design information. With these as a basis the research program was pointed toward maximum chemical and gasoline production. This involved considerable catalyst development and the proper choice of operating conditions.

An economic evaluation of the process in the U. S. in 1948 showed that the advantages which looked attractive a few years earlier were rapidly disappearing because of high cost natural gas. Research activity was consequently curtailed until the latter part of 1950 when the opportunity of applying the know-how in this field to the Sasol project was realized.

The Synthesis Unit at Sasol contains two reaction systems. Synthesis gas feed to the unit is approximately 6 million SCFH.

The Kellogg synthesis reactor is designed specifically for close temperatures control and high efficiency of contact between catalyst and gas. The design is quite different from conventional fluid catalyst systems. With this design catalyst concentration or residence in the reactor is controllable in two ways, by catalyst circulation rate and gas velocity. Fine temperature control is attained with tubular coolers in the catalyst circuit. In these coolers reaction heat is transferred to a circulating oil system which is used to generate 200 psig steam in a waste heat boiler. The highly exothermic heat of reaction is controlled as follows:

1. Regulating the flow of catalyst in the reaction system,
2. The quantity of cold gas introduced and
3. Transfer of heat from the catalyst to the oil cooling system.

After passing through a separator and two stages of cyclones the overhead vapors from the synthesis reactor enter an oil scrubbing tower where the final traces of fine catalyst are removed in a concentrated slurry. In this same tower the heavy oil from the synthesis is condensed and decanted off from a settling section of the tower to the oil recovery unit. Heat from the overhead vapors entering this tower is removed in a circulating system. The effluent vapors from the scrubber tower are cooled and condensed further in water coolers and are separated into three phases—a gas phase, an oil phase and a water phase.

The gas is neutralized with alkali and water washed prior to entering the oil recovery unit. The oil is water washed for partial chemical removal and fed to the clay treating section of the oil recovery unit. The water used for washing is combined with the primary synthesis product water, also containing chemicals, and sent to the chemical recovery unit.

Preliminary operations of the Synthesis Unit began in the fall of 1955. Good temperature control and steady, smooth catalyst and gas flow conditions proved the soundness of the reactor design. The catalyst losses in the system have been lower than the make-up required to maintain catalyst activity and have in general been well below design.

Several problems developed during the course of operation of the unit, and steady consistent operation was not attained until the spring of 1956. Since that time the operating efficiency of the unit has improved a great deal and at the present moment is being brought up to design production. This appears to be mainly a problem of improving operating efficiency and making a modification to the compressors within the unit.

Production has also been curtailed because it has been necessary to revise the waste water removal system from the chemical plant. Since the Vaal River is the only source of water in this area and thus farms and cities are entirely dependent upon it, very stringent precautions are necessary to

prevent contamination. It is expected that the new acid removal plant will be ready for operation in early November of this year. At that time the entire plant should be ready to go into full design production.

**Oil and Chemical Product Treating and Recovery Units**—Product gas from the Synthesis Unit passes through an oil absorber tower where the bulk of the $C_3$ fraction and all the $C_4$ and heavier hydrocarbons are removed. Part of the tail gas leaving this unit is used for fuel gas in the refinery. Oil product from the Synthesis Unit oil scrubber tower is combined with the water washed oil from the Synthesis Unit and the mixture is vaporized and passed over a fixed bed catalyst where all residual oxygenated compounds are converted to pure hydrocarbons and the octane of the gasoline is raised. Regeneration of the bed is carried out by passing a mixture of air and nitrogen over the bed at elevated temperatures.

Condensed oil from the clay treating operation is combined with stripped product from the lean oil stripper of the absorber system and is sent to a debutanizer tower. The overhead from this tower plus some extraneous $C_3$'s and $C_4$'s from the Arge Synthesis and if it is desired $C_3$'s and $C_4$'s which have been produced by dehydration of propanol and butanol in the chemical plant are fed to a catalytic polymerization unit.

All hydrocarbon products are now combined and fractionated to give as final products LPG, a stabilized gasoline of about 7 RVP (dictated by the altitude in the area of sales), diesel oil and heavy waxy oil.

In the chemical plant the chemical-containing water stream from the Synthesis Unit is fractionated. In this operation all the oxygenated products and their azeotropes, except the organic acids, are carried overhead. The acid water stream from the bottom is neutralized with lime and the resulting organic salts are recovered by vacuum distillation in triple-effect evaporators. Further separation of the overhead from the primary fractionator is carried out in a distillation tower where the carbonyls and methanols are stripped from the alcohols. Distillation of these light components yields, as products, methanol (make up for the gas purification unit), ketones and crude alcohols produced by catalytic hydrogenation of the aldehydes. The bottom alcohol fraction from the carbonyl stripper is dried by azeotropic drying with benzene and hydrogenated to remove traces of aldehydes. Ethanol, propanol and butanol are fractionated out as separate products. At the present time most of these alcohols are added to part of the hydrocarbon gasoline for sale as a blended gasoline. A batch still is provided for processing the other chemical products present in smaller quantities.

The operating history of the units in this area has been very good. After a short breaking-in period all continuous units have performed in accordance with design and products have met the required specifications.

**Cooling Water Plant Facilities**—Cooling water facilities for the entire refinery are centrally located. The system consists of forced draft cooling towers above concrete basins with adjoining sluiceways. It has been divided into a "clean water" circuit serving the large surface condensers throughout the refinery and an oily water circuit for cooling process streams. The cooling towers are subdivided into cells with nine cells on the clean water side and 12 cells on the oily water side. Individual cells may be isolated from the circuit for cleaning. Six turbine-driven water pumps, one a spare, take suction from the sluiceway and distribute the water to various sections of the plant. Normal design cooling water requirements are approximately 190,000 gallons per minute. The water is treated by chlorination to control algae, acid is added to control pH and phosphate is added to inhibit scaling in the refinery coolers.

**Ash Handling Facilities**—At normal plant capacity approximately 1600 tons of total ash consisting of boiler fly ash, boiler bottom ash, and gasifier residue must be removed from the plant each day. Fly ash from the dust separator hoppers in the power plant is removed by an automatic hydrovactor system to the main ash sump. Bottom ash from the boilers is sluiced to a collecting basin from which it is pumped to the main ash sump. Gasifier residue sluiced from the Lurgi generators passes through clinker grinders on its way to the same sump. Large slow-speed slurry pumps deliver this agitated mixture of ash and water to the ash disposal bed outside the refinery. An accumulator earth dam is located below this bed to recover the ash water for recycling and disposal after treating.

The water for the ash disposal operations is supplied from a sump which collects refinery waste water streams as well as the ash water recycle stream. From this sump high pressure pumps take suction to supply water to the hydrovactor system and sluicing nozzles.

**Other Facilities**—Plant facilities include the following: a railway system with two diesel driven switch engines, a fire fighting system with a main fire house and substations throughout the refinery plus a separate water main and pump station, drum filling and handling facilities, rail car and truck loading racks, equipment repair and maintenance shops, equipment and chemical stores, a large service garage, and a completely equipped modern two story research and analytical laboratory including a mass spectrometer and X-ray equipment.

**Summary of Operation**—Service facilities including coal handling, power generation and water circulation began preliminary operations late in 1954. The first oxygen plant went into production early the following year. Within a few months the gas producers were sending gas to the gas purification unit. In mid-year operations were begun in the reforming section and by fall the first synthetic gasoline was being produced.

During the last year some mechanical changes were found necessary in several sections of the plant. These are being completed largely while operation continues. Development of synthesis catalyst from local ore has been carried on toward allowing operation entirely on this material. For these reasons the production rates have not yet reached the design values, but are improving steadily. It is expected that before the end of this year, with the mechanical changes completed, the plant can attain full scale production. # #

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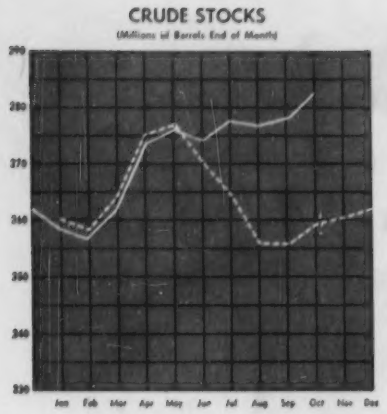
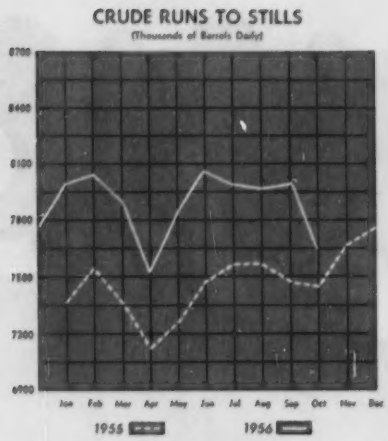
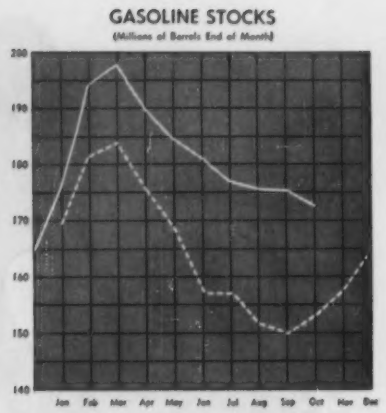
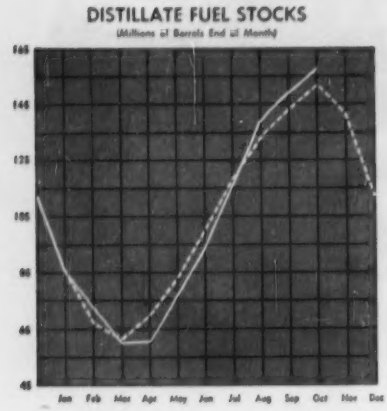
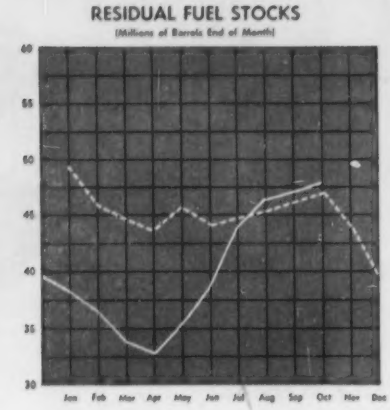
For more data on advertised products, use Readers' Service Cards, last page.

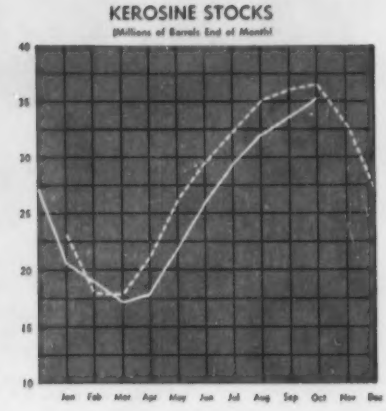


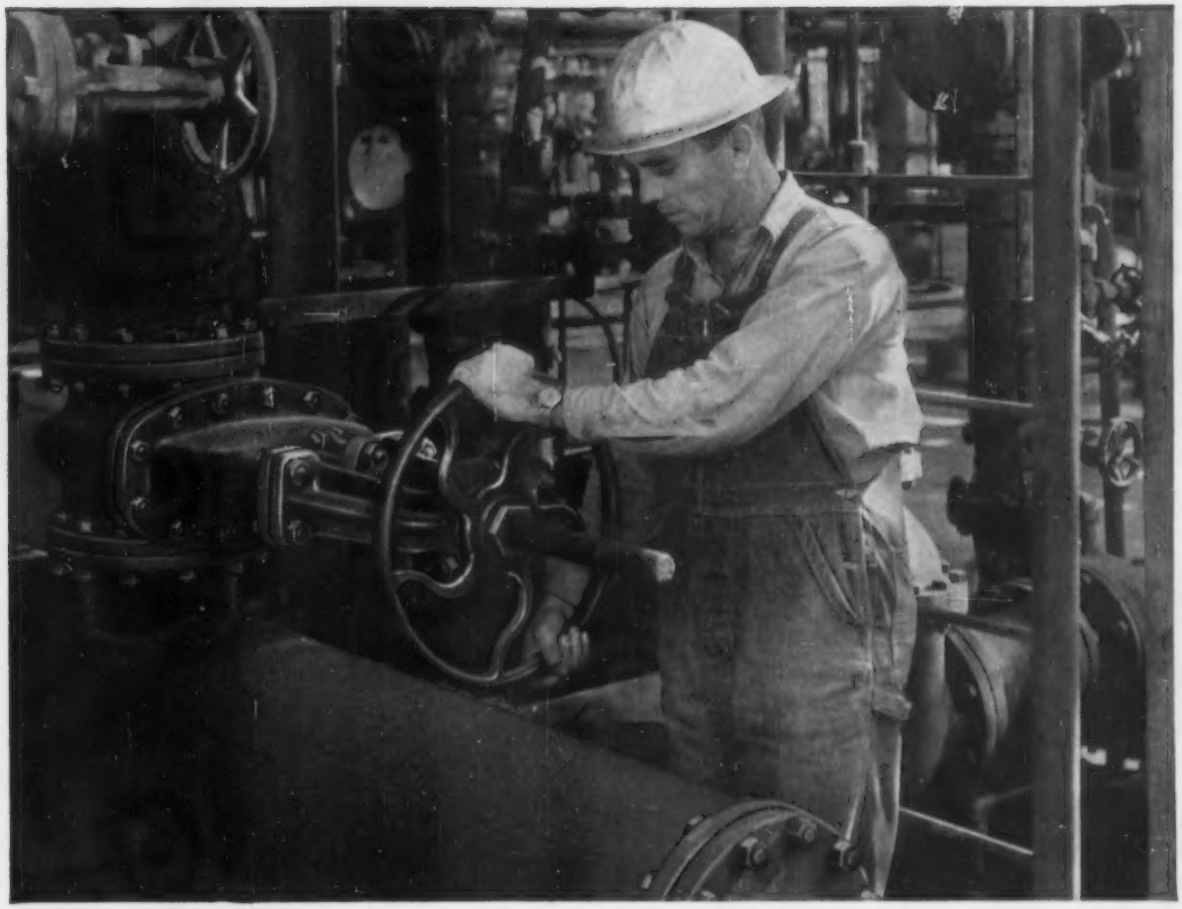

# Taking Stock

**Cecil W. Smith**
Economics Editor

- **Refining rates cut sharply**
- **Crude stocks at 2½-year high**
- **October's imports near peak**

| MONTH | CRUDE OIL | | | GASOLINE | | KEROSINE | | DISTILLATE FUEL | | RESIDUAL FUEL | | DAILY IMPORTS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Production Daily | Runs to Stills Daily | Stocks End of Month | Production Daily | Stocks End of Month | Production Daily | Stocks End of Month | Production Daily | Stocks End of Month | Production Daily | Stocks End of Month | Crude Oil | Total Oils |
| **1954:** | | | | | | | | | | | | | |
| October | 6,135 | 6,834 | 269,442 | 3,457 | 149,661 | 310 | 37,140 | 1,545 | 139,128 | 1,066 | 56,541 | 642 | 1,065 |
| November | 6,346 | 6,975 | 264,566 | 3,530 | 150,604 | 354 | 34,547 | 1,622 | 133,886 | 1,120 | 54,891 | 636 | 1,104 |
| December | 6,394 | 7,238 | 258,385 | 3,605 | 155,400 | 381 | 27,826 | 1,668 | 108,144 | 1,187 | 52,105 | 729 | 1,301 |
| **1955:** | | | | | | | | | | | | | |
| January | 6,761 | 7,379 | 260,156 | 3,639 | 169,562 | 409 | 23,266 | 1,740 | 86,692 | 1,235 | 49,457 | 739 | 1,348 |
| February | 6,835 | 7,549 | 258,630 | 3,655 | 181,643 | 374 | 18,291 | 1,847 | 68,513 | 1,239 | 46,042 | 751 | 1,379 |
| March | 6,886 | 7,374 | 264,430 | 3,543 | 183,972 | 357 | 18,187 | 1,703 | 62,457 | 1,185 | 44,970 | 742 | 1,319 |
| April | 6,887 | 7,136 | 275,232 | 3,502 | 175,601 | 312 | 21,486 | 1,534 | 70,139 | 1,110 | 43,838 | 697 | 1,123 |
| May | 6,677 | 7,281 | 276,948 | 3,605 | 164,751 | 296 | 26,375 | 1,519 | 83,559 | 1,111 | 45,083 | 742 | 1,137 |
| June | 6,613 | 7,484 | 270,850 | 3,725 | 157,439 | 269 | 29,830 | 1,628 | 100,652 | 1,080 | 44,398 | 764 | 1,159 |
| July | 6,632 | 7,580 | 264,601 | 3,824 | 157,079 | 286 | 32,749 | 1,575 | 119,169 | 1,091 | 44,894 | 860 | 1,161 |
| August | 6,665 | 7,580 | 256,427 | 3,858 | 151,912 | 290 | 35,292 | 1,621 | 133,675 | 1,090 | 45,480 | 756 | 1,155 |
| September | 6,731 | 7,483 | 256,269 | 3,784 | 150,194 | 279 | 36,361 | 1,621 | 143,248 | 1,061 | 46,267 | 829 | 1,218 |
| October | 6,837 | 7,465 | 267,346 | 3,827 | 153,103 | 309 | 36,705 | 1,612 | 152,288 | 1,123 | 47,040 | 821 | 1,206 |
| November | 7,014 | 7,692 | 260,707 | 3,867 | 157,871 | 341 | 33,283 | 1,680 | 141,808 | 1,214 | 44,071 | 823 | 1,322 |
| December | 7,155 | 7,762 | 265,610 | 3,916 | 165,433 | 395 | 26,770 | 1,765 | 111,333 | 1,286 | 39,174 | 884 | 1,502 |
| **1956:** | | | | | | | | | | | | | |
| January | 7,199 | 8,023 | 261,592 | 3,927 | 183,905 | 385 | 21,310 | 1,923 | 86,141 | 1,344 | 38,247 | 805 | 1,422 |
| February | 7,208 | 8,047 | 259,504 | 3,854 | 196,092 | 385 | 18,712 | 1,918 | 71,335 | 1,286 | 35,673 | 878 | 1,472 |
| March | 7,278 | 7,914 | 265,683 | 3,829 | 199,698 | 342 | 17,215 | 1,808 | 60,846 | 1,213 | 32,984 | 934 | 1,425 |
| April | 7,146 | 7,487 | 277,121 | 3,646 | 193,299 | 299 | 18,227 | 1,713 | 63,571 | 1,130 | 32,740 | 815 | 1,305 |
| May | 7,064 | 7,896 | 277,497 | 3,859 | 186,673 | 292 | 21,883 | 1,667 | 75,928 | 1,149 | 36,607 | 938 | 1,416 |
| June | 7,100 | 8,071 | 274,491 | 3,976 | 177,076 | 290 | 26,111 | 1,755 | 93,758 | 1,098 | 39,073 | 987 | 1,426 |
| July | 7,090 | 8,014 | 277,008 | 3,975 | 176,536 | 296 | 28,990 | 1,767 | 115,787 | 1,066 | 43,958 | 1,084 | 1,463 |
| August | 7,195 | 7,995 | 279,944 | 4,037 | 172,939 | 313 | 31,826 | 1,839 | 137,905 | 1,091 | 46,617 | 1,001 | 1,399 |
| September | 7,046 | 8,011 | 278,415 | 3,923 | 175,268 | 332 | 33,571 | 1,819 | 149,751 | 1,102 | 47,413 | 1,017 | 1,421 |
| October | 6,996 | 7,638 | 283,164 | 3,744 | 172,534 | 359 | 35,133 | 1,776 | 158,483 | 1,107 | 47,988 | 1,005 | 1,461 |
| **Week Ended:** | | | | | | | | | | | | | |
| 11-16-56 | 7,159 | 7,965 | 280,221 | 3,783 | 172,739 | 374 | 35,978 | 1,738 | 160,460 | 1,127 | 46,768 | 832 | 1,247 |
| 11-18-55 | 6,851 | 7,657 | 255,539 | 3,759 | 153,580 | 336 | 35,144 | 1,707 | 148,661 | 1,177 | 45,293 | 827 | 1,206 |

**Source:** Data for last two months from API; prior monthly data from Bureau of Mines. Data in thousands of barrels.



# No leakage, no sticking with this Crane valve after 2 years on heavy alkylate at 300° F.

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It handles re-run bottoms from the $H_2SO_4$ alkylation unit at 300° F. In addition to erosion from solid carbon, there is mild corrosion present from acid. Valve operation is on an average of once every 1½ weeks.

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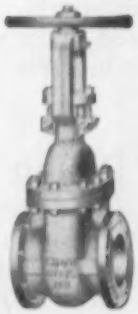

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For more data on advertised products, use Readers' Service Cards, last page.

## On Nomographs

Here's a "How To Do It" item that will be particularly interesting and beneficial to those who at some time or other have to calculate pumping cost data. Its a nomograph that simplifies pumping-cost calculations so that several can be done in the same time it took for one long hand calculation. Here it is, ready for you to cut out and use, with a full explanation of, "How To Do It."

**Keep Going to Page 234**

## Who's Building What?

A new source of LPG in the Gulf Coast area is the plant recently completed by Tennessee Products Pipe Line Co. Read the details of this and other construction projects all over the world. Whether the construction is planned, under way, or completed, you read about it in "Who's Building."

**Keep Going to Page 241**

## "Piping Switchboards"

Read about the new system of flexible hose links combined with quick connect "snap on" hose couplings that is being used as a "piping switchboard." These switchboards have begun to appear in chemical, oil refining, and other processing plants where they meet all requirements for practical application in high-capacity, high-pressure fluid lines. It's all explained in "What's New In Equipment and Manufacturer's Literature."

**Keep Going to Page 362**

## The Long Road Back

The last of the postwar reconstruction articles is running this month and deals with the phenomenal growth of Royal Dutch/Shell Companies in Europe. Read the highly interesting and factual account of how this company rose "From Chaos to Europe's Leading Refiner."

**Keep Going to Page 280**

## Petroleum Prognostications

In 1957, the daily domestic demand for petroleum products will run about 965,000 barrels, a four percent increase over 1956. In 1962 the domestic demand will have risen to 11,000,000 barrels a day; a 20 percent increase. You might also be interested in the new bombardment process that will eventually lead to plastic cars, buildings, and aircraft. These and many other items are presented in a concise manner to help you keep up with "What's Happening in the Industry."

**Keep Going to Page 287**

## "Petroleum Facts and Figures"

The twelfth edition of "Petroleum Facts and Figures" has been published by the American Petroleum Institute, and is the most convenient source of information in the petroleum industry. Read the complete review of this book and others in "Reviewing New Books."

**Keep Going to Page 331**

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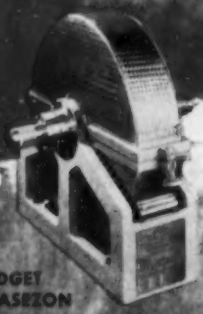
## Hermetically-Sealed Centrifugal Clarifier and Separator

From eye-dropper capacity (200 cc) to a Niagara Cascade (1000 GPM)



MIDGET PHASEZON (200 cc capacity)

**From eye-dropper capacity (200 cc) to a Niagara Cascade (1000 GPM)**

The PHASEZON is applicable to the separation of any two immiscible liquids, even where the specific gravity difference is minute. / Since it is hermetically-sealed, it is especially well adapted to handling highly volatile solvents and very viscous liquids. The working area is completely protected from solvent vapors. Overflow and spillage are impossible. Flows are arranged so clarified products cannot be contaminated by feed or each other. / Unique mechanical features spell the difference between the PHASEZON and conventional-type equipment. / Interface is controlled by a simple adjustment outside the PHASEZON during operation . . . no disassembly is necessary when feed stocks are changed. / Centrifugal force up to 5000 G's, coupled with expansive coalescing area, low-liquid velocities and retention time, promotes high quality separation and clarification. Quick effective cleaning without rotor disassembly minimizes downtime and makes the PHASEZON available for more production hours per day. / High through-puts are obtained in small equipment . . . equipment cost is at a minimum.

*Write us about your requirements and ask for questionaire.*

*Patents and patents pending

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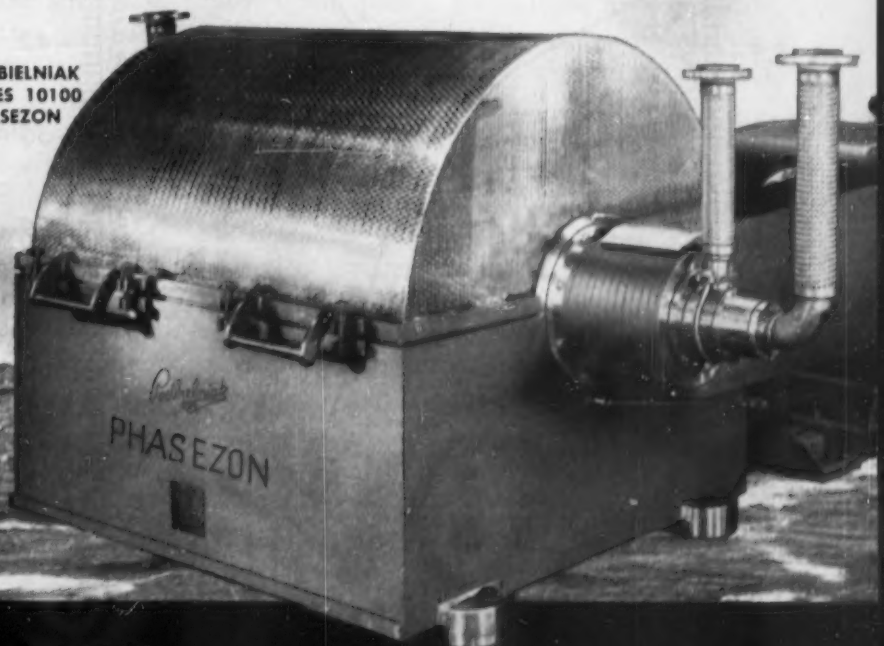


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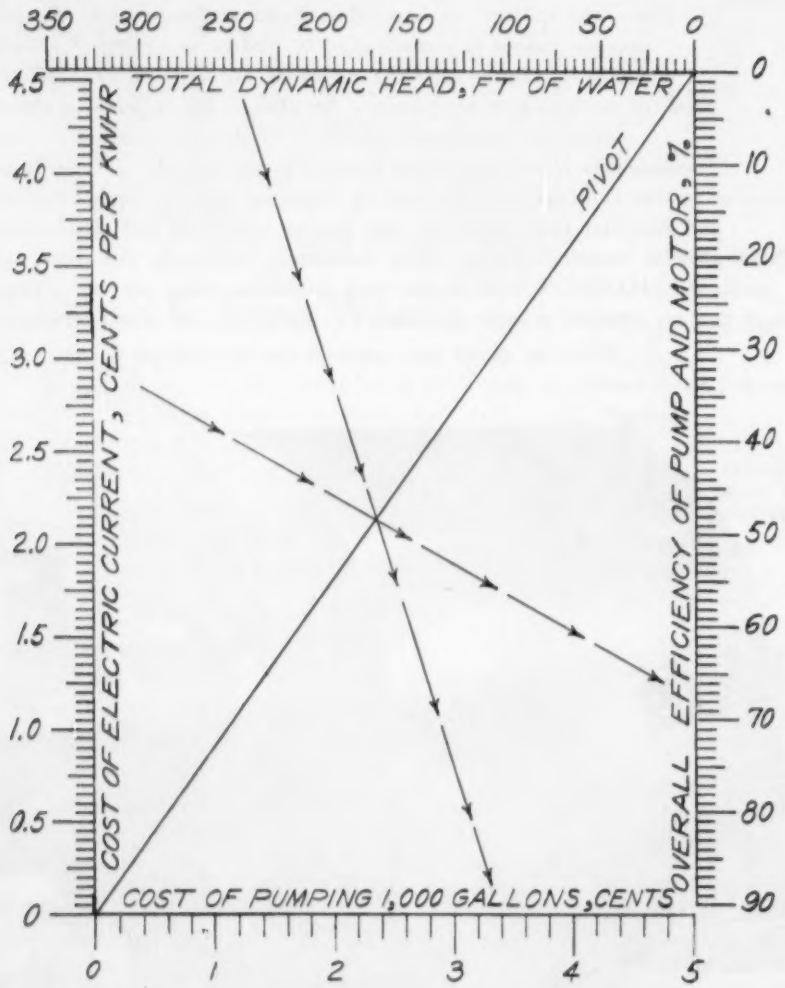
# How To Do It . . .

*For Quick Pumping Cost Data . . .*

# Use This Easy-to-Handle Nomograph

**Here's how to eliminate tedious calculations, particularly when different pipe sizes are considered.**

A major factor governing many engineering decisions is the cost of doing a certain job. This fact is often met in petroleum-plant design and operation, especially when considering the pumping of fluids. Computation of pumping costs can be tedious, particularly when several different pipe sizes are being considered. This chart simplifies pumping-cost calculations and permits several to be made in the same time needed for one long-hand calculation. Here's how it's used.


350 300 250 200 150 100 50 0
TOTAL DYNAMIC HEAD, FT OF WATER
4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0
COST OF ELECTRIC CURRENT, CENTS PER KWHR
PIVOT
0 10 20 30 40 50 60 70 80 90
OVERALL EFFICIENCY OF PUMP AND MOTOR, %
COST OF PUMPING 1,000 GALLONS, CENTS
0 1 2 3 4 5

**Example:** A pump with an efficiency of 80 percent is driven by a motor with an efficiency of 85 percent. What is the cost of pumping 1,000 gallons of water when electricity costs three cents per kwhr and total dynamic head on pump is 250 feet?

*Solution:* Over-all efficiency of pump and motor is (80 percent) (85 percent) = 68 percent. Enter the chart at the left and from three cents per kwhr on the current-cost scale draw a straight line through 68 percent over-all efficiency on the right-hand scale. Then, from 250-feet dynamic head on the upper scale draw a straight line through the intersection of the first line with the pivot line. On the bottom scale read 3.4 cents, cost of pumping 1000 gallons of water.

Note that pump capacity need not be known to use this chart. Where fluids other than water are pumped, (oil, gasoline, benzene, etc.), simply multiply the cost found from the chart by the specific gravity of the fluid.

**Example:** What would pumping cost be if oil with a specific gravity of 0.85 were handled under the same conditions as in the above problem?

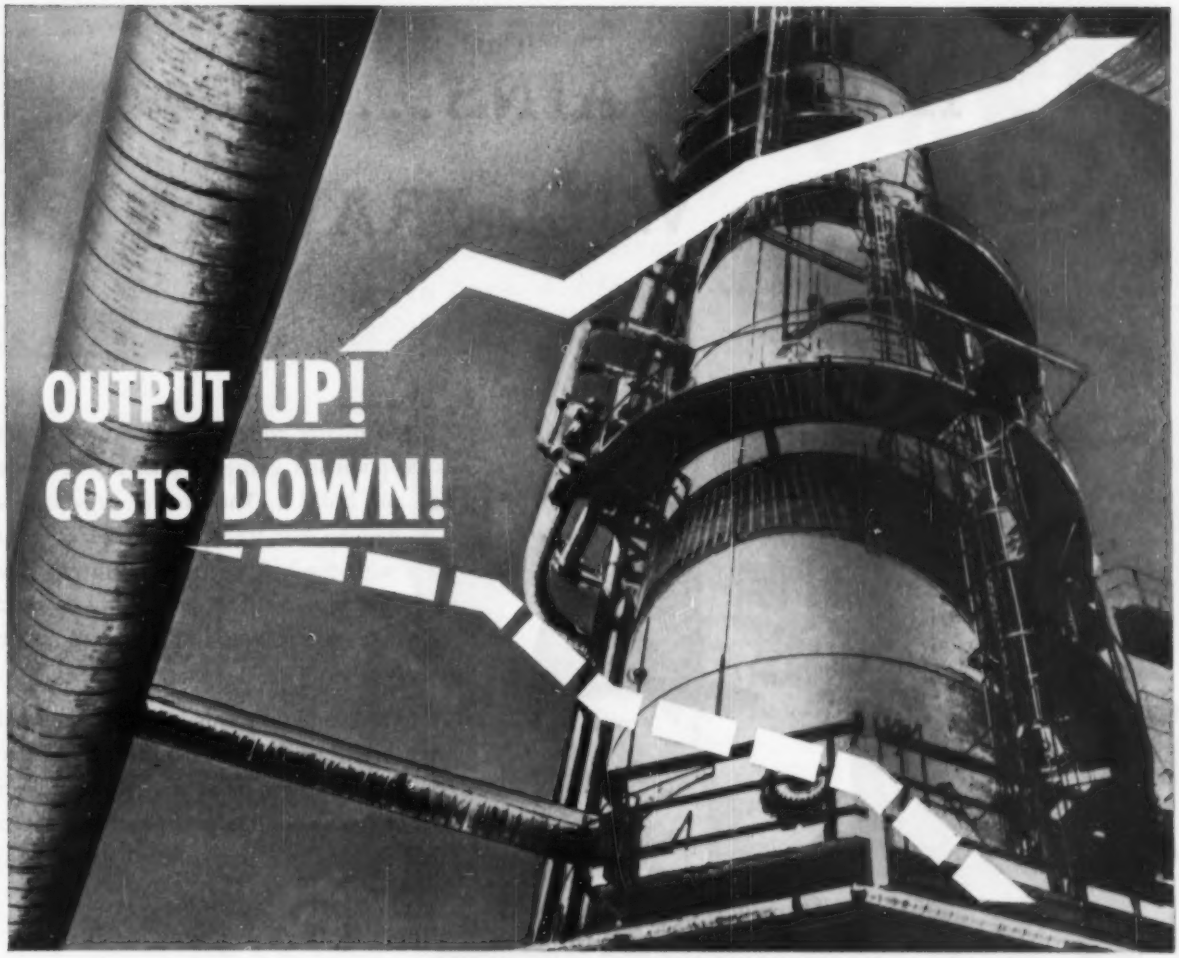
*Solution:* Solve as before. Then cost = 3.4 (0.85 = 2.89 cents per 1000 gallons pumped.

Total dynamic head given on this chart covers the range most often met in petroleum-plant pumping jobs.

This nomograph was prepared by T. G. Hicks, Hicksville, N. Y.

## Suck Mud Siphon

Maintenance personnel are often required to drain fluid from pumping

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METEX Hi-Thruput Mist Eliminators, installed in process towers and vessels, effect sharp separation of liquids and gases. Quality and yield are increased. Valuable liquids are knocked out and returned. Contamination of subsequent processing is removed. Turbines and compressors are protected from damaging liquids. Where build-up of coke or solids is a consideration, on-stream service life is increased three to four times. Air pollution is reduced, too.

METEX Hi-Thruput Mist Eliminators provide virtually 100% removal efficiency, even at extreme temperatures and pressures. Pressure drop is negligible. Their outstanding performance is due to repositioning of the wires by the METEX patented Herringbone Fold . . . an exclusive development of the originators of knitted wire mesh entrainment separators. Impingement target area is increased and stagnation points reduced.

In any processing equipment or vessels where liquid entrainment is a contributing factor in design or operation, specify METEX Hi-Thruput Mist Eliminators to assure greater production, improved quality of yield and substantially reduced operating and maintenance costs.

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6-201

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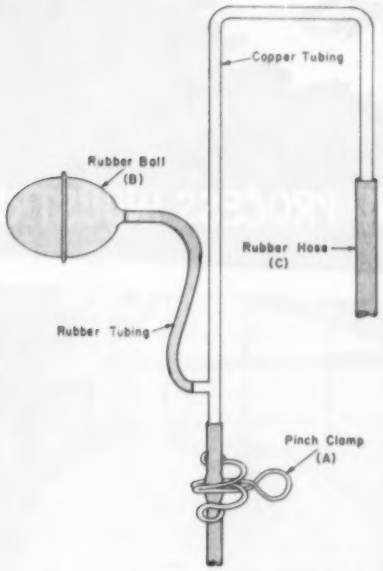
equipment at locations where no drains are provided.

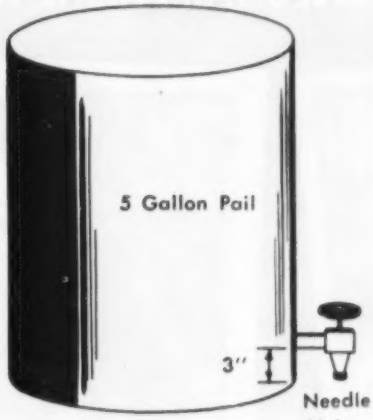



The most convenient method of draining fluid from this equipment is by the use of a siphon. The gadget illustrated allows the maintenance man to remove the fluid without putting the siphon tube in his mouth in order to partially evacuate the tube. It is called a "Suck Muck Siphon."

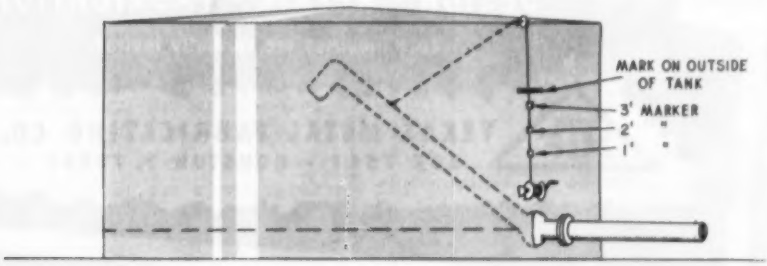
To remove the fluid, the operator places hose "C" in the fluid, closes pinch clamp "A", deflates the rubber ball "B", releases "B" and waits a few seconds, opens "A" and watches the fluid come out of "D".

## How to Do It...

## Use a Simple Bucket To Apply Antifoam




A needle valve is inserted in a standard 5 gallon pail, which is placed on or above the foaming vessel. The needle valve is adjusted to the desired flow for efficient foam control. A "once-a-shift" filling of the pail is usually all that is required.




## Markings Show Swing Position in Tank

On storage tanks with swing suction lines, it is often impossible to determine from the operator's position how far the swing may be lowered without picking up basic sediment and water. A simple tank marking and the attachments shown remove all doubt.

First determine the highest expected level of bs&w in the tank and lower the swing to one foot above this surface. An arrow or similar marking is painted on the outside of the tank adjacent to the swing line. At the same level as the arrow, a brass clamp about ⅜-inch wide is attached to the swing line. This clamp is stencilled "1 foot."

The swing is then raised another foot above the bs&w. Another clamp is attached to the swing line, this time at the new position that lines up with the arrow. This clamp is marked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3 **Flush Mounted Dial Thermometer** for panel mounting with flexible connecting armor.

All three types have a full 4½" dial face.

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**for interchangeability:** Always specify "PALMER" Separable sockets as they are interchangeable for Dial or Industrial type Thermometers.

**Send for Bulletin 51-129** for details on the New Palmer Dial Thermometer.

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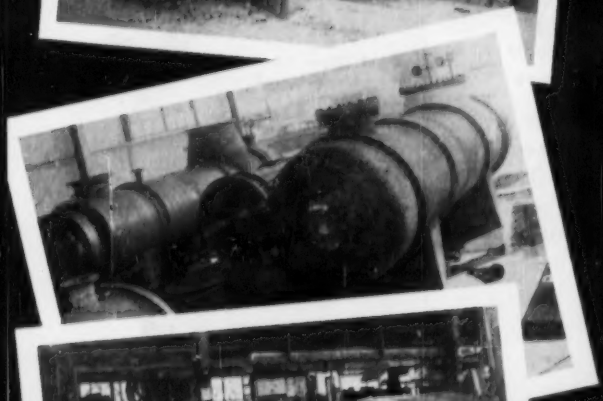

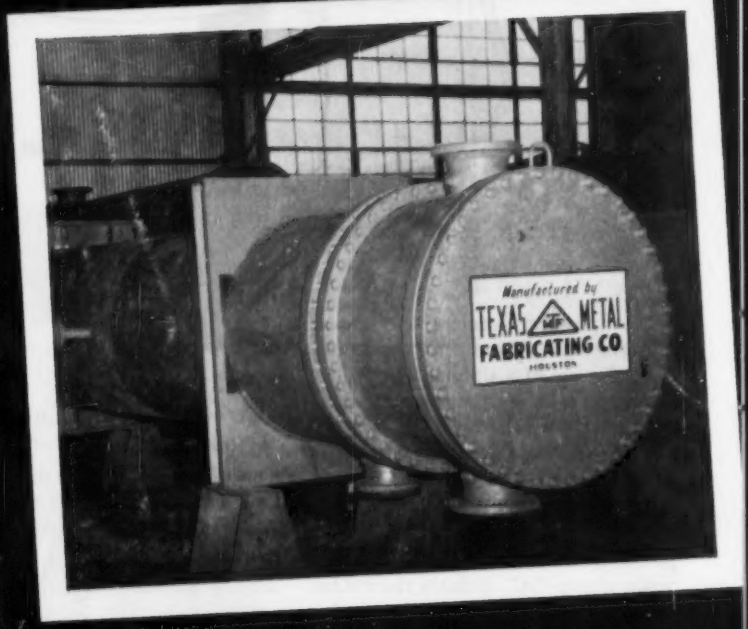


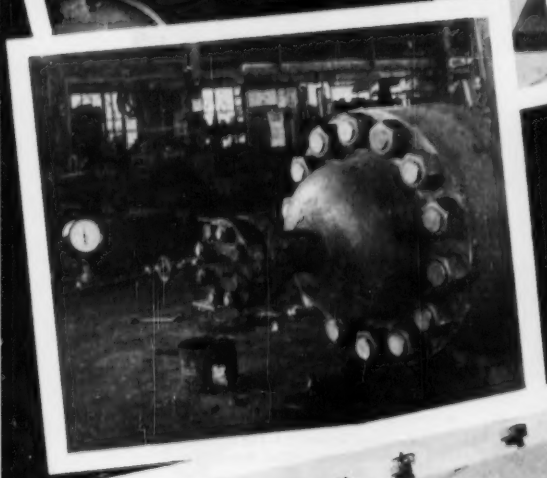

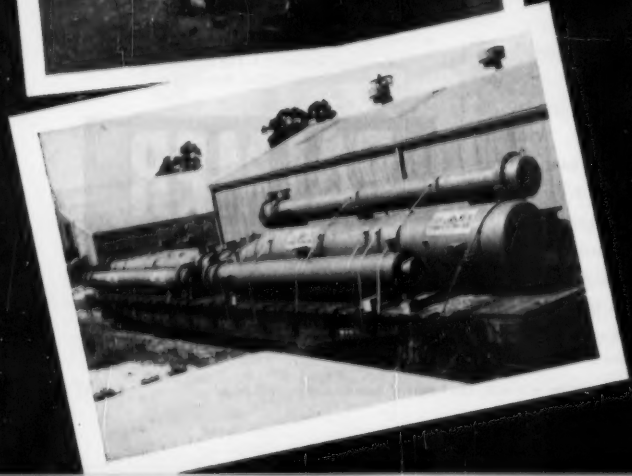

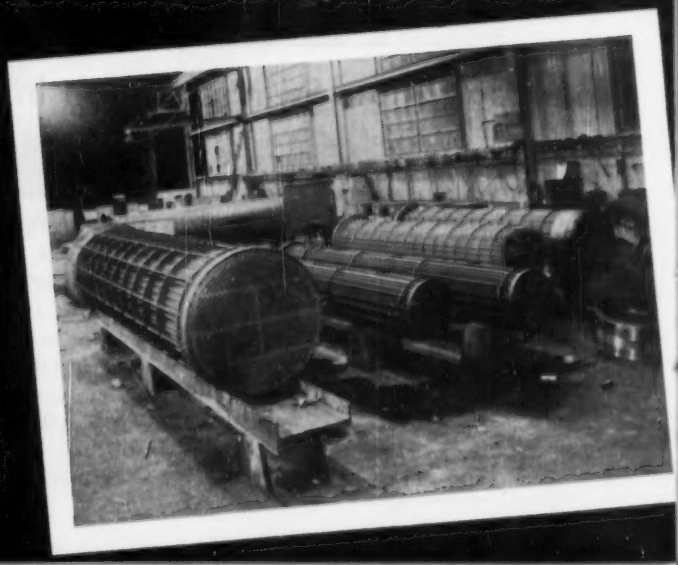

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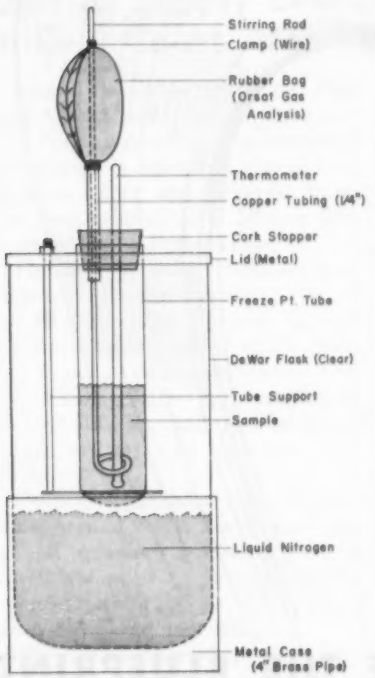
API-ASME AND ASME CODE CONSTRUCTION

"2 feet." A third clamp marker may also be added to indicate the 3-foot mark.

With this arrangement, the man at the winch knows at all times how far the swing's mouth is from the bs&w.




## Run Freeze Points The Easy Way

Those who run freeze-points on products with liquid nitrogen know how essential it is to keep moisture containing air out of the apparatus and still stir the liquid. The usual way is to use packing around a stirring rod but this cramps the rod and does not prevent the end of the stirrer from breaking the surface of the liquid. The idea, as illustrated, is to clamp a rubber bag around the stirring rod and insert a length of quarter inch copper tubing in a cork stopper. This arrangement keeps air out of the apparatus and at the same time allows free movement of the stirring rod. The bag is also clamped on the stirring rod in a position which prevents pulling of the stirrer end above the liquid surface.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You'll keep plant production and efficiency way up... practically eliminate costly down-time due to tube failure, with AIRETOOL Condenser Tube Maintenance equipment. Even at "turn-a-round" time, lost stream, time is kept to a minimum. Repair, removal and replacement of tubular equipment is accomplished faster, easier and at less cost, with AIRETOOL equipment on the job.

Don't wait... investigate all the advantages of AIRETOOL Condenser Tube Maintenance Equipment now. There's a precision built AIRETOOL tube maintenance tool for every type of tubular construction. See your nearest AIRETOOL Representative today... or write AIRETOOL MFG. CO., Springfield, Ohio, for information.

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quickly removes damaged or leaky tubes. Cuts through steel or non-ferrous tube sheets to 4" thick. Air or electric driven motor.

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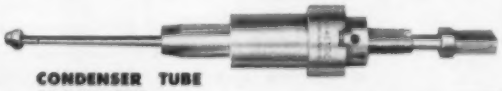
for non-ferrous tubes ⅝" to 1" O.D. cuts through tube sheets 1" to 4" thick. Operates on your own air or electric motor.

**CONDENSER CLEANERS**
outside mounted, direct or gear driven. Powerful . . . fast . . . lightweight . . . for lightly scaled or completely plugged tubes. Built in flushing system cools drill, removes cuttings.



**CONDENSER TUBE EXPANDERS**
parallel rolling, self-feeding, ball bearing thrust. Rolls tubes to uniform thickness, with maximum bonding.

**AIRETOOL MIDGET CLEANERS**
for lightly scaled tubes. Small, powerful, excellent for cleaning small tubes with extremely short radii turns or hairpin bends.

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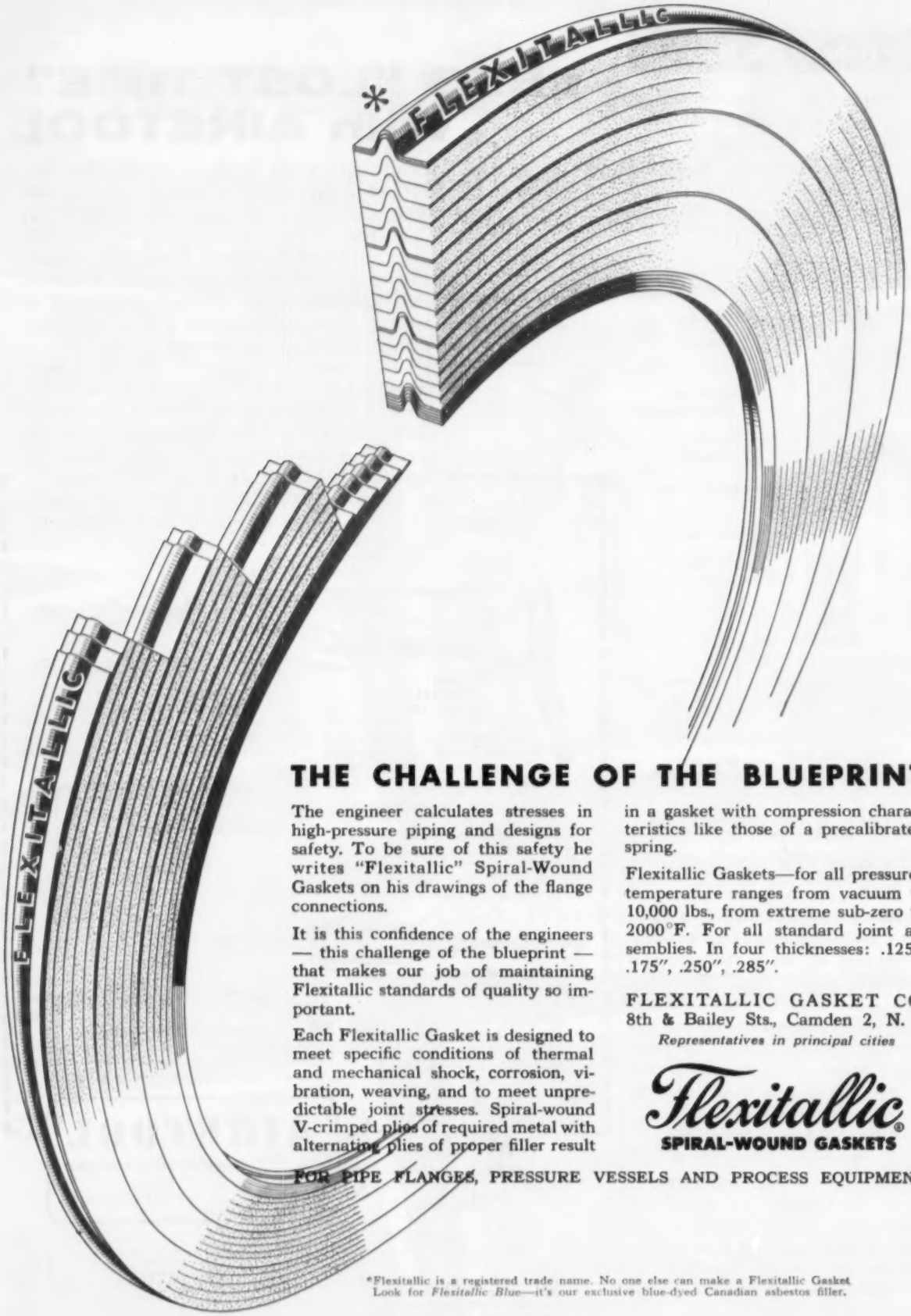


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Flexitallic Gaskets—for all pressure/temperature ranges from vacuum to 10,000 lbs., from extreme sub-zero to 2000°F. For all standard joint assemblies. In four thicknesses: .125", .175", .250", .285".

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# Who's Building . . .

# Tennessee Gas Completes La Porte Plant

## New Fractionation Unit to Supply LPG In Gulf Coast Area

THE TENNESSEE PRODUCTS PIPE Line Co., a subsidiary of Tennessee Gas Transmission Co., has completed and placed in operation a new fractionation plant and related transportation facilities on a 50-acre tidewater site at La Porte, Texas.

The new facilities, constructed at Barbour's Cut on the west side of the Houston Ship Channel, include the fractionation plant, which processes liquefied petroleum gases; a battery of storage tanks, and installations for the loading and unloading of barges, railway tank cars and tank trucks.

Output of the plant includes propane, normal butane, iso-butane and natural gasoline, separated from a mixed stream of liquid hydrocarbons received through the company's newly-completed pipe line.

The fractionation plant is connected by an underwater pipeline crossing of the ship channel with an underground storage area at the Barber's Hill salt dome 13 miles northeast in Chambers County. Tennessee Products is developing five LPG storage wells there, with a combined storage capacity of 1,250,000 barrels.

Propane and normal butane from the fractionation plant are being stored there. Upon completion of the expansion program now underway at the Houston plant of the Petro-Tex Chemical Corp., normal butane will be piped to that plant from Barber's Hill for use as a feedstock for making butadiene, an ingredient of synthetic rubber.

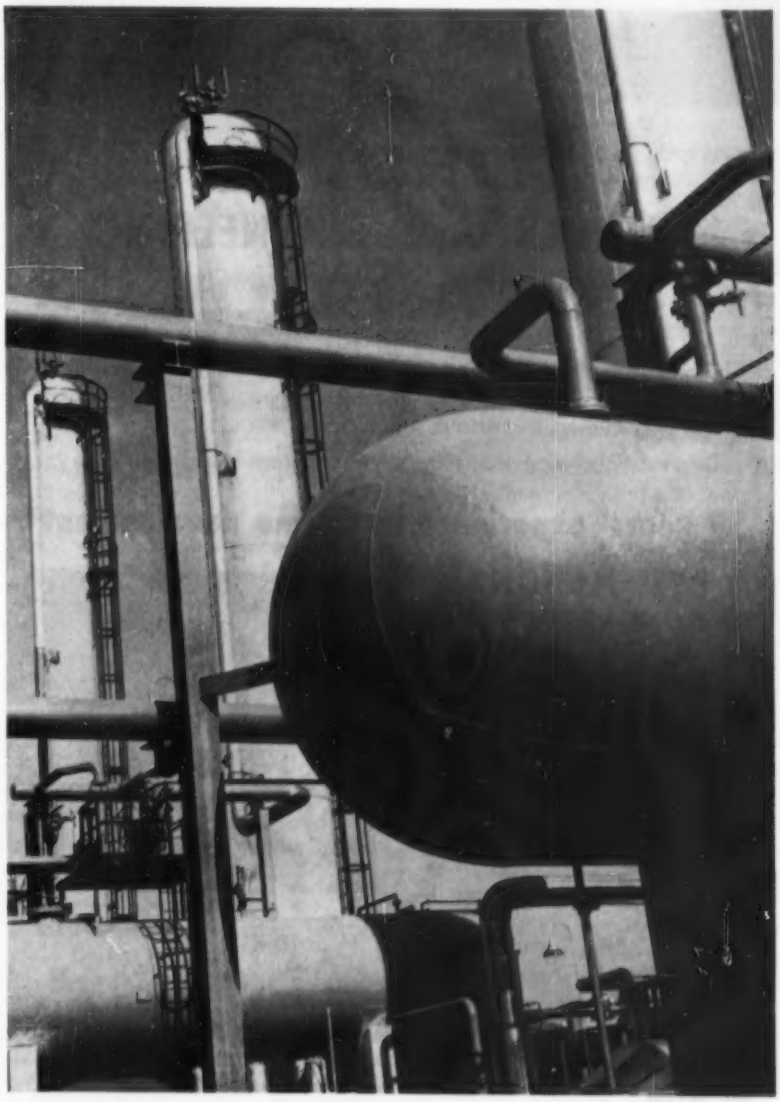
Petro-Tex is jointly and equally owned by Tennessee Gas and by the Food Machinery and Chemical Corp.

The iso-butane and natural gasoline are moved directly from the fractionation plant by pressure barge, tank truck and railway tank car to customer refineries, including the New Orleans refinery of Bay Petroleum Corp., another Tennessee Gas subsidiary, for use in the production of motor fuels.

During periods of heavy demand, propane from the fractionation plant may be shipped direct without storage for use in petrochemical processes and for home fuel having no natural gas service.

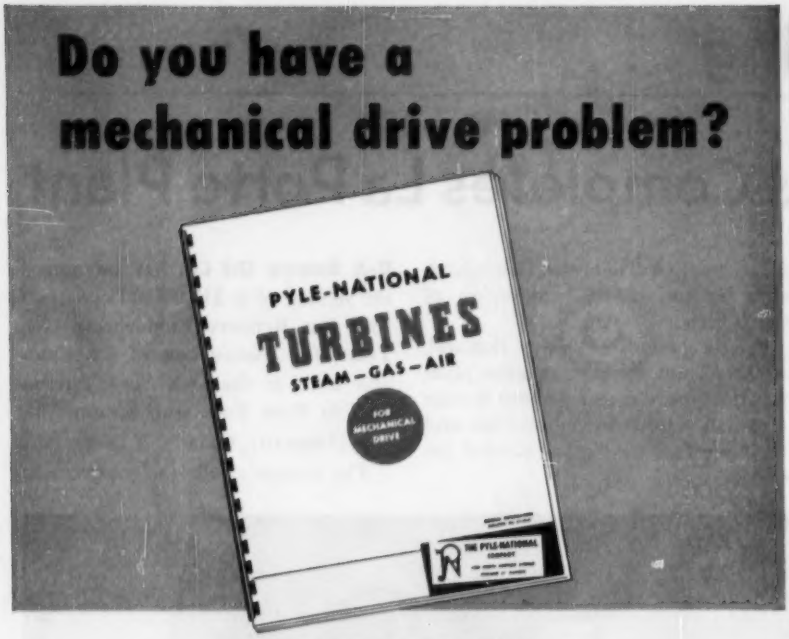
**D-X Sunray Oil Co.** has announced the signing of a $10,000,000 contract with the Refinery Engineering Co., Tulsa, for construction of six major new units at the D-X Sunray refineries in West Tulsa and Sunray Village (Duncan), Okla.

The contract calls for construction



**Gleaming towers mark the Tennessee Products Pipe Line Co.'s fractionation plant now in operation on the Houston ship channel near La Porte, Texas. The plant produces propane, normal butane, iso-butane, and natural gasoline.**

# Do you have a mechanical drive problem?




# TURBINE SELECTION AND ENGINEERING DATA BOOK

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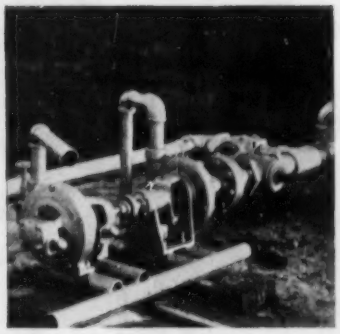
- Rugged!
- Trustworthy!
- Easiest of all turbines to service and maintain!



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## Who's Building. . .

the 70,000 barrel West Tulsa refinery of a 20,000 b/d naphtha unifiner; a 12,000 barrel platformer with a re-run column; a 1417 barrel liquefied petroleum gas recovery unit; a 2453 barrel butane isomerization unit; and a 2470 barrel HF alkylation unit with a debutanizer and re-run column.

At the 40,000 barrel Sunray refinery at Sunray Village, Treco will construct a 6000 barrel naphtha unifiner (pre-treating unit).

Construction is expected to be under way by January 1 with completion tentatively scheduled for the last quarter of 1957.

**Union Oil Company of California** has announced plans for immediate construction of a multi-million dollar plant to manufacture 100 million pounds of ethylene annually, utilizing refinery gas as its basic raw material. The plant, to be completed early in 1958, will be located at the company's Los Angeles refinery.

A substantial portion of the production from this plant will be delivered by pipeline to the Brea Chemicals-Koppers Co., joint venture for manufacture of polyethylene. The balance will be available for sale to chemical manufacturers.

**Battelle Institute** has completed the nation's first privately owned nuclear research center. The announcement followed initial "start-up" of the Institute's one-million-watt research reactor. The ¾ million dollar reactor is the largest of the "pool type" yet to be put in service in this country. It is designed exclusively for research purposes and will use solid uranium-235 fuel.

The new reactor is basically a nuclear apparatus for producing gamma rays and neutrons. It will be used in research on the chemistry of petroleum, sterilization of pharmaceutical products, preservation of agricultural goods, and improvement and development of numerous chemical, glass, plastic, ceramic, and metallic products and processes.

**Standard Oil Co. (Indiana)** is planning to build a new chemical plant costing in excess of $10 million to manufacture chemicals under a new process. As yet, the site of the new plant is undetermined, but company officials say that it will be somewhere in the Midwest.

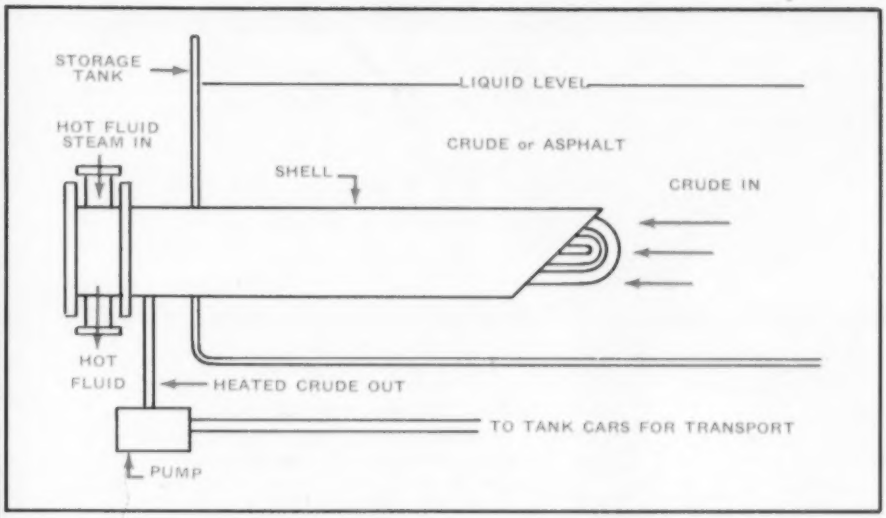
The plant will use a new hydrocarbon oxidation process to make phthalic anhydride, isophthalic acid, terephthalic acid, dimethyl terephthaliate, dimethyl isophthalate, and benzoic acid.

The plant will be built and operated by Amoco Chemicals Corp., an Indiana Standard affiliate. Construction is due to start early next year, with completion date slated for sometime in 1958.

**Lion Oil Co.,** a division of Monsanto Chemical Co., has started construction on a nitric acid concentrator at its El Dorado chemical plant. The addition, which represents a substantial investment, will concentrate 58 per cent nitric acid now being manufactured at two existing units. It is expected to produce, under normal operation, 40 tons per day of nitric acid of 95 per cent strength, which will be used primarily as a raw material by another


For more data on advertising products, use Readers' Service Cards, last page.

# TEXANS SHOW HOW TO HURRY CRUDE FROM STORAGE




## FINNED U-BEND TUBES SPEED WORK, CUT COSTS

**by Ernest Dodd**

Down Texas way, engineers are using a highly efficient and economical method for putting a little hustle into crude as it is moved from storage tanks at ambient temperatures.

Instead of tank suction heaters using prime surface tube, the Texans designed new heaters around Wolverine Trufin® Type S/T, finned tube of electric-welded steel, in U-bend form. The results—from the standpoint of both performance and economy—have been most satisfactory.

For example, because its integral fins give Trufin more than twice the effective heat transfer surface of plain tube, it was possible to design smaller heaters using fewer tubes. The result was a substantial saving in direct tube costs.

Despite their smaller size, the new units —with super-heated steam on the tube side—heat the crude from normal temperatures to 250°-300° F. This allows large quantities of the highly viscous crude to be withdrawn from the tank at a greatly increased rate of flow. The design used is a simple, single shell side pass over the U-bend tubes.

In addition to outstanding performance and the direct savings made in tube alone, the use of Wolverine U-bend tubes also contributed further savings in labor and material.

U-bend tubes were prefabricated by Wolverine to exchanger prints and packaged in expendable pallets in the exact order of their installation. On receipt of shipment it was only necessary for the equipment manufacturer to feed them directly from the pallet into the unit. Their use also resulted in the elimination of one tube sheet, a reduction by half of rolling-in operations and the elimination of floating head problems.

## TRUFIN TYPE S/T IS WIDELY USED

Day by day throughout the entire heat transfer field, Wolverine Trufin Type S/T is being used in an increasingly large number of applications. Typical of the uses to which engineers are putting this capacity-boosting and cost-cutting integral finned tube, are: condensing freon and other refrigerants, condensing hydrocarbons, condensing organic chemicals, evaporating freon—water chillers, boiling hydrocarbons, heating or cooling gases, heating or cooling lube oils, transformer oils, absorber oils and quench oils.

Type S/T can be specified in any of a wide range of sizes and alloys in copper, aluminum or electric-welded steel. It is available with either 16 or 19 fins per inch. Because its integral fins give added support on bends, Trufin Type S/T can be fabricated just as readily as plain tube.

## GOT A PROBLEM? JUST ASK F.E.S.

Among the many services Wolverine maintains for the convenience of its customers is the staff of highly trained tubing technicians in its Field Engineering Service.

These men, in addition to their individual training and knowledge, can draw on Wolverine's background of tubing experience to help solve customers' problems in design, corrosion, fabrication, etc. The staff is available at all times and their services impose no obligation.

## SEND FOR FREE BOOK!

One of the most comprehensive sources of information available on finned tube is Wolverine's Trufin Opportunity Book. In addition to much background data, this book contains valuable information on designing with integral finned tube. There are a number of actual Trufin case histories describing performance boosts and cost reductions made possible by Trufin Type S/T. There is no charge for this book. Write for your copy—today.

## INTERCHANGEABILITY

Complete interchangeability with prime surface tube is an important feature of Wolverine Trufin Type S/T. When retubing with Type S/T, only standard tools and tubing techniques are required. There is no deviation from normal procedure.

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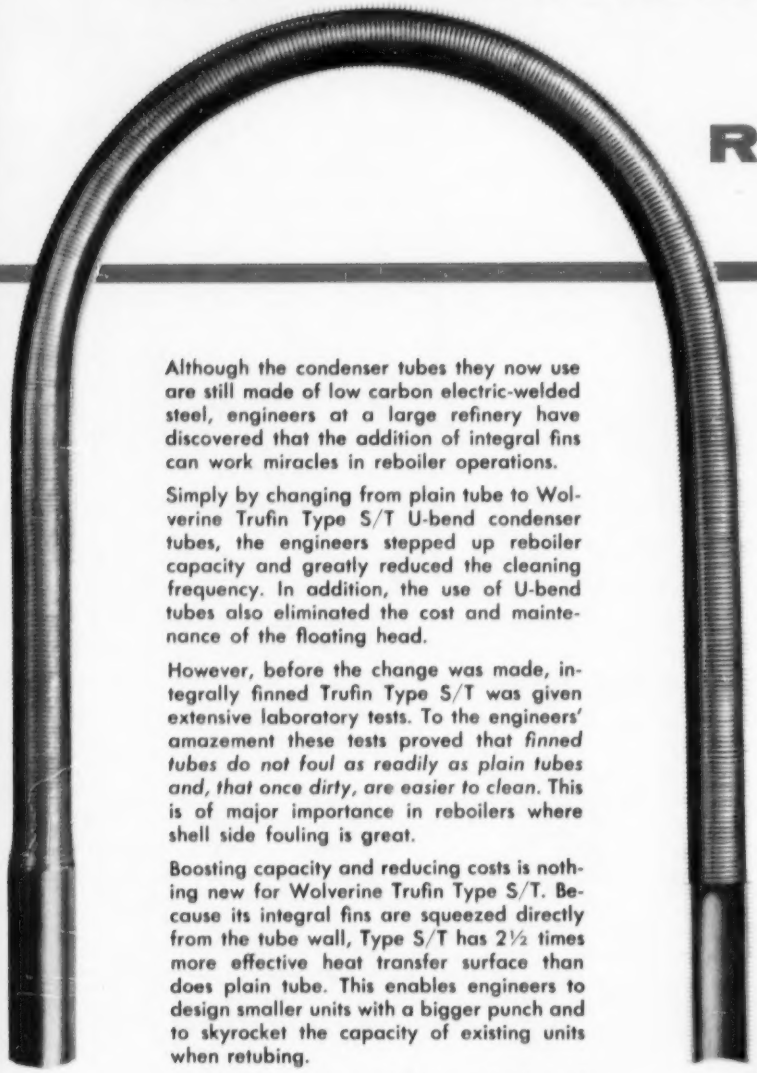
# *the* CONDENSER TUBE *for* REBOILERS



Although the condenser tubes they now use are still made of low carbon electric-welded steel, engineers at a large refinery have discovered that the addition of integral fins can work miracles in reboiler operations.

Simply by changing from plain tube to Wolverine Trufin Type S/T U-bend condenser tubes, the engineers stepped up reboiler capacity and greatly reduced the cleaning frequency. In addition, the use of U-bend tubes also eliminated the cost and maintenance of the floating head.

However, before the change was made, integrally finned Trufin Type S/T was given extensive laboratory tests. To the engineers' amazement these tests proved that *finned tubes do not foul as readily as plain tubes and, that once dirty, are easier to clean.* This is of major importance in reboilers where shell side fouling is great.

Boosting capacity and reducing costs is nothing new for Wolverine Trufin Type S/T. Because its integral fins are squeezed directly from the tube wall, Type S/T has 2½ times more effective heat transfer surface than does plain tube. This enables engineers to design smaller units with a bigger punch and to skyrocket the capacity of existing units when retubing.

In addition to its exclusive production of integrally finned condenser tube, Wolverine is also a direct mill source for prefabricated U-bend tubes.

Wolverine ships U-bends to the user in expendable pallets. They are removed in the exact order of their installation — reducing unit fabrication time, eliminating one tube sheet and cutting rolling-in operations by half.

If your plant operates reboilers, Wolverine Trufin Type S/T U-bend condenser tubes can help you increase capacity and reduce costs. Specify them for new equipment or when retubing. For complete information write for your copy of the Wolverine Trufin Catalog.

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Manufacturers of Quality-Controlled Tubing and Extruded Aluminum Shapes

*Wolverine Trufin available in Canada through the Unifin Tube Company, London, Ontario*

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## Who's Building...

at Monsanto plant. Included in the construction will be blending facilities which will also permit the production of 68 per cent nitric acid.

Construction contractor and designer of the installation is Chemical and Industrial Construction Co., a subsidiary of Chemical and Industrial Corp. of Cincinnati, Ohio. Completion is scheduled for March, 1957.

**Mellon Institute** has announced plans for construction of a million-dollar laboratory to house its recently established department of radiation research. The structure will be built on a newly-acquired 125-acre rural tract located about 20 miles east of Pittsburgh near the town of Export, Pa.

The new suburban research center represents the first major expansion of facilities for the institute since completion of its present large laboratory building, close to the University of Pittsburgh campus, in 1937.

Construction of the radiation research building will get under way this fall and is expected to be completed by late summer of 1957. It will house the institute's first major source of radiation, a powerful 3-million-volt Van de Graaff accelerator now on order from High Voltage Engineering Corporation in Cambridge, Massachusetts. Pending installation of the institute's own particle accelerator, arrangements have been made for part-time use of a similar radiation machine now installed in the Pittsburgh area.

Also included will be laboratories for radiochemical and allied work, general laboratories, office space, a radiation library and equipment for using radioactive materials.

**The Standard Oil Co. (Ohio),** board of directors has authorized an expenditure of $40 million for a new refinery facility at its Toledo, Ohio, refinery. It is expected that actual construction will start early in April, and that the new facility will be completed by April 15, 1958.

The M. W. Kellogg Company and Sohio's engineering staff designed the facility which will replace part of the present refinery. The new refining unit is rated at 60,000 barrels per day capacity, a net increase of 32,000 barrels over present facilities.

Sohio's new refinery facility at Toledo will combine in one operation area and in one unit, atmospheric and vacuum crude distillation, delayed coking, catalytic cracking, hydrogenation, catalytic polymerization, catalytic reforming, gasoline recovery and stabilization, treating and continuous gasoline blending and steam generation processes. A central communications center will be provided for overall coordination.

**Jefferson Chemical Co.** plans a major expansion of its petrochemicals plant at Port Neches, Texas. The program will triple production facilities for ethylene, double the plant's capacity for ethylene glycol, and increase by 50 per cent the production of ethylene oxide.

It will include installation of a direct oxidation unit to produce ethylene oxide, but Jefferson also plans to continue oper-

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## Who's Building...

ation of its existing chlorohydrination equipment and will produce ethylene oxide by both processes.

In addition, Jefferson will construct a plant to produce chlorine; much of the caustic soda resulting from the process will be marketed, while the hydrogen will be used by the company. Plans also call for stepped-up output of a number of other chemicals, including specialty amines.

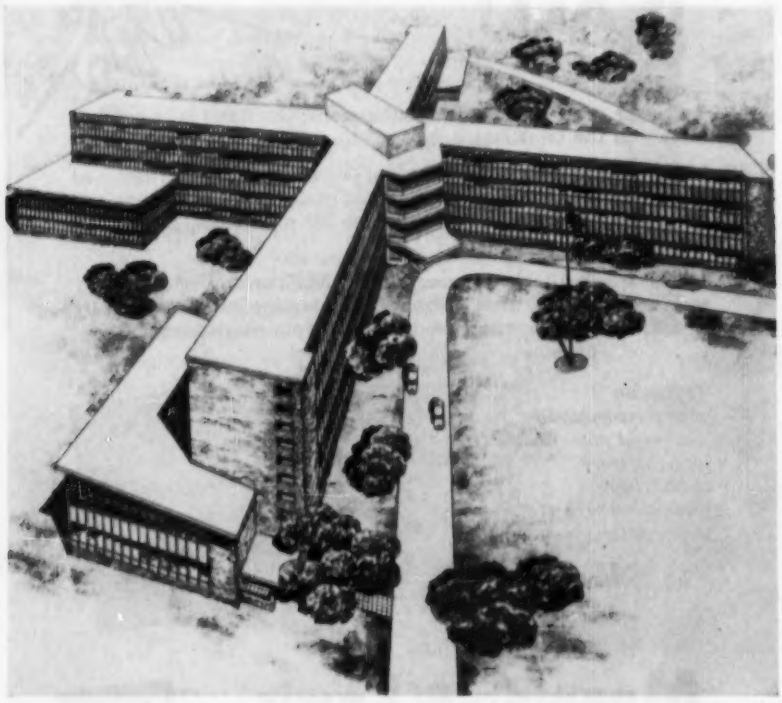
**Socony Mobil Oil Co.** has awarded a contract to J. F. Pritchard Co. to build a 3250 barrel a day catalytic reformer, and a hydrogen desulfurizing unit to treat oils and diesel fuels at its Casper, Wyo., refinery. Both the new units are expected to be on stream by the fall of 1957.

**Esso Standard S.A.F.** has announced that it will start work shortly on a new refinery at Bec-d' Ambes in southwest France. The new plant will have an initial capacity of 11.25 million barrels a year and is expected to be on stream by 1959. It will have a catalytic reformer.

The company also announced that by the first quarter of next year it will complete the catalytic cracking unit presently being constructed at its Port Jerome refinery near Le Havre. The unit's capacity is set at 7.8 million barrels a year. Construction of a hydroformer is also being contemplated for this same refinery.

### *Tidewater's Pumping Station—*

**Workmen make final adjustments to the giant pumps which will form the heart of a vast cooling system serving Tidewater Oil Co.'s new Delaware Flying A refinery now being built 15 miles south of Wilmington. Nine 2,000 horsepower pumps will draw 275,000 gallons of water per minute from the Delaware River and send it through about 15 miles of pipe to cool the refinery processing units after doing its cooling job. The ultramodern refinery, now nearing completion, is expected to be in large scale production early next year.**



### *Carbide and Carbon's "X" Building—*

**Architect's drawing shows how new Engineering Building of Carbide and Carbon Chemicals Co., a Division of Union Carbide and Carbon Corp., will look when completed at South Charleston, W. Va., in 1958. Building will house more than 500 engineers who design new plants and equipment for the company's continuing expansion program. Fellheimer and Wagner of New York were the architects. This building, in the form of an X, will be adjacent to a new development laboratory.**

**Gulf Oil Corp.** had acquired options to purchase over 3000 acres of land near Charleston, S. C. A Gulf spokesman said the company presently was making detailed investigations of the site to determine whether it might make a satisfactory location for a new refinery at some future date.

Gulf officials emphasized that extensive investigations were necessary before any decision could be made as to the practicality of the location's use as a refinery site. In addition, considerable further study of various factors will be required before the potential size and nature of any such refinery can be determined.

**Shell Development Co.** will consolidate its agricultural research activities under one roof at Modesto, Calif.

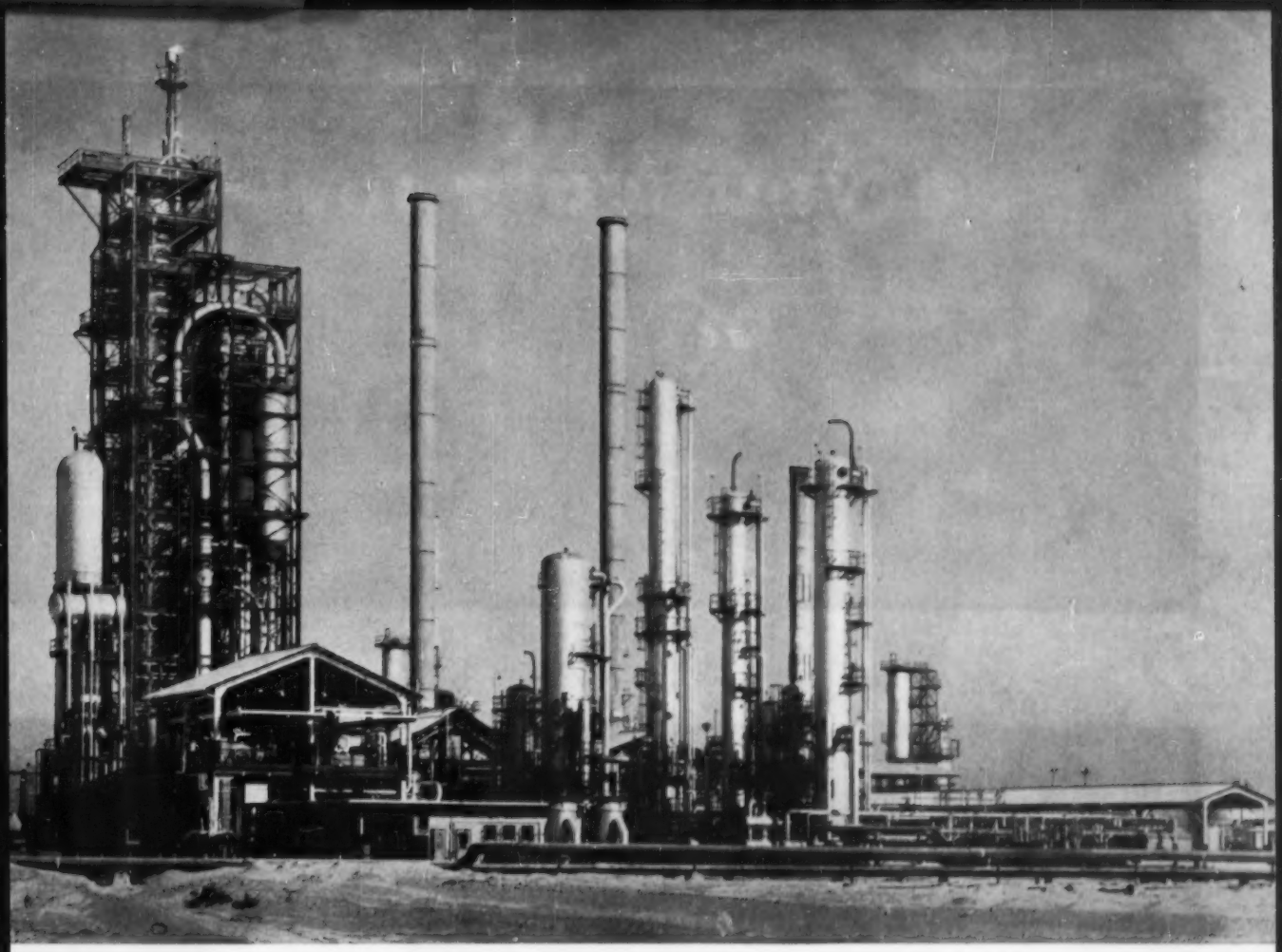
Plans for the consolidation, according to Dr. H. Gershinowitz, president, provide for a large increase in present facilities at Modesto to house that portion of the firm's agricultural research staff presently located in Denver, Colorado.

An estimated $1,000,000 will be spent by Shell for new buildings and services. Construction is scheduled for completion by fall, 1957.

"Six major new laboratories and office buildings will be added to the present group," Dr. Gershinowitz stated.

**Magnolia Petroleum Co.** has completed the world's largest centrally located underground storage facilities for liquefied petroleum gas at Hull, 50 miles northeast of Houston. The project, begun over two years ago, consists of six storage wells 1100 to 2400 feet underground with a total capacity of over 1,200,000 barrels.

A direct pipe line tie-in with Magnolia's refinery in Beaumont, Texas, permits



# Lummus, Aramco teamwork supplies more quality gasoline from Saudi Arabia

In August at Ras Tanura, Saudi Arabia, a 12,500 B/D Fluid Hydroformer is undergoing its first turnaround since it came on stream in October, 1955. For the past 10 months this unit has supplied 92.5 F-1 clear octane blending stock to European and Middle East markets, where the need for quality gasoline is growing rapidly.

The Hydroformer was designed and engineered by Lummus for The Arabian American Oil Company under license from Esso Research and Engineering Co. The process, though more complex than any other in the Ras Tanura Refinery, was designed for ease of operation to fit in with the Company's policy of training and upgrading Saudi Arab nationals to the fullest extent.

Close liaison among the three groups during all phases of design and construction has paid off. Startup was smooth, with all facilities operating at full design rate soon after feed was introduced. And the plant has been operating successfully ever since, at and above the design rate. In all cases, hydroformates of premium quality have been obtained from the high paraffin – low naphthene stocks characteristic of Arabian crudes.

Test runs at feed rates of 12,500 – 16,300 B/D have yielded products of 94.8 – 87.4 F-1 clear octane. There has been no difficulty in making the 92.5 octane design product at rates up to about 13,500 B/D. These tests indicate that hydroformates close to 95 F-1 clear can be produced in good yields, and should higher quality be needed, more severe hydroforming conditions appear to be feasible.

Aramco's new Hydroformer is one of over 700 major Lummus installations throughout the world. The excellent operating record of this new unit, and of Lummus plants in general, proves the case for coordinated direction of a project from idea to startup. Lummus teamwork can pay off on your next project.

THE LUMMUS COMPANY, 385 Madison Avenue, New York 17, N. Y. *Engineering and Sales Offices:* New York, Houston, Montreal, London, Paris, The Hague, Bombay. *Sales Offices:* Chicago, Caracas. *Heat Exchanger Plant:* Honesdale, Pa. *Fabricated Piping Plant:* East Chicago, Indiana. *Engineering Development Center:* Newark, New Jersey.

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Yes, you can get low-cost, yet effective protection against contamination and corrosion with all these chemicals...and many more!

Effective in heavy industrial applications where the corrosion rate does not exceed 0.0015 inches per year, CF&I LECTRO-CLAD Nickel Plated Steel Plates successfully combine the corrosion and contamination resistance of nickel and the economy and strength of carbon steel.

That's because CF&I LECTRO-CLAD is made by the Bart Process, which consists of electrodepositing a heavy layer of 99% pure nickel on a carbon steel plate. This process results in a permanent bond between the nickel and the steel base. The nickel plating is customarily supplied in the 8-10 mil range; however, it can be plated up to 15-20 mils, if specified.

What's more, CF&I LECTRO-CLAD Nickel Plated Steel Plates are easily fabricated without costly special equipment. Just use regular shop equipment and bend it... weld it... roll it—the protective nickel layer will not check, spall or flake!

Ask our nearest sales office for the complete story on economical, effective, easy-to-fabricate CF&I LECTRO-CLAD Nickel Plated Steel Plate today. Wickwire Spencer Steel Division, The Colorado Fuel and Iron Corporation, P. O. Box 1951, Wilmington, Delaware.

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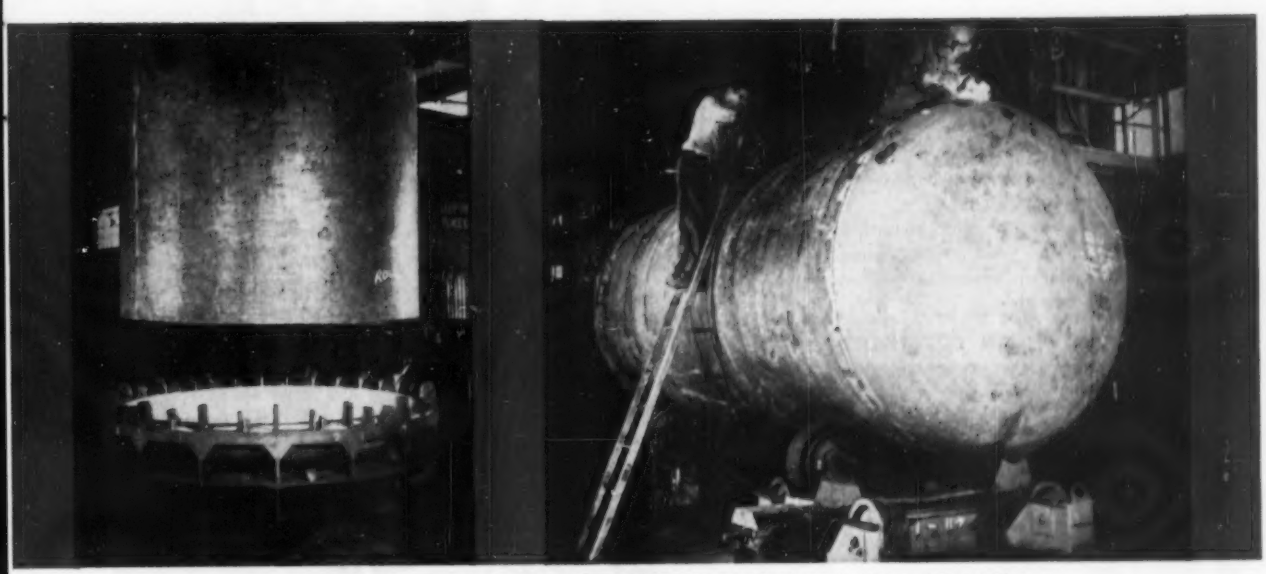
Methyl Alcohol • Petroleum Catalysts • Phenol • Potash • Resin Plasticizers • Salt
Sodium Sulphate • Titanium Dioxide • Tricresyl Phosphate



Assembling a tank fabricated from CF&I LECTRO-CLAD Nickel Plated Steel Plates.

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## Who's Building. . .

storing of excess LPG received, fractionated and produced at the plant. It relieves above-ground tankage at the refinery which formerly had to cope with LPG requirements for both gasoline blending and contract commitments.

Other underground leaching operations by Magnolia are being carried out in Midland, Texas, where two 50,000-barrel cavities will provide pipe line surge space. This space is being leached out of a salt layer formation rather than a salt dome. Completion is expected in mid-1957.

**National Petro-Chemicals Corp.** has started increasing capacity of its Tuscola, Ill., polyethylene plant. When completed in 1957, the expanded facility will have a rated capacity of 100 million pounds per year. Currently National Petro-Chem is producing about 50 million pounds per year although it was originally designed for just a 26 million pound-per-year capacity.

Cost of the expansion program which will be completed in mid-1957 is expected to reach $10 million.

**Imperial Chemical Industries, Ltd.,** plans a second glycol plant accompanied by increased ethylene oxide capacity, for its Wilton Works in North Yorkshire. Plant is scheduled to come into operation in 1959 when a third olefin plant now under construction will be completed. The two Imperial plants will have a combined capacity of 16,000 tons.

**Forth Chemicals, Ltd.,** has completed expansion of its styrene monomer plant at Grangemouth, Scotland. Company officials expect the new capacity to satisfy all British needs for styrene monomer without importing.

**The Texas Company's** recent acquisition of the assets of Trinidad Oil Co. has resulted in a proposed $70 million 100,000 barrel-per-day refinery to be built by Caltex for Regent Oil Company Ltd, near Southampton, England. The plan is awaiting approval by the British government. If aproval, design, and construction are all expedited, the refinery might go on stream late in 1958.

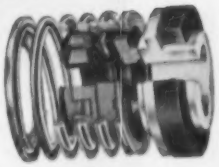
**The Syrian Government** has been reported reconsidering a Czech offer to build a 20,000 barrels per day, $16 million refinery in Syria. Tenders from eight nations had been received, with the Czech offer apparently being viewed most favorably.

**Bay Petroleum Corp.** has completed construction of a multi-million dollar improvement program at their Chalmette refinery below New Orleans. Refinery capacity was increased to 23,500 barrels per day. The new facilities include a 5000 barrel a day platformer unit, and additions and improvements to the crude and catalytic cracking units.

**Firestone Tire and Rubber Co.** is completing construction of a new multi-million dollar synthetic rubber plant which has added 50,000 tons annually to the capacity. A new expansion program which is to commence in December will add still

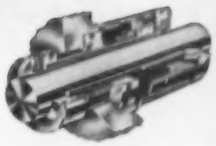

3 JOHN CRANE Shaft SEALS
for lifetime performance in any petroleum or petrochemical service

TYPES 1 and 2
Synthetic Rubber Bellows • For Low Pressure Service



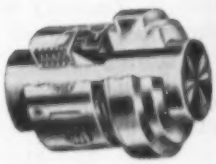
Services: gasoline, diesel fuel, fuel oil, crude oil, butane, propane, ethane and similar products non-injurious to synthetic rubber.
Pressures: to 200 psi.
Temperatures: —40°F to +212°F.
Construction Data: Factory assembled. Self-adjusting sealing head. Lapped faces positively prevent leakage. Low spring pressure for minimum wear. *Available in balanced construction for pressures to 550 psi.*

TYPE 8B
Packaged Type Seal • For High Pressure Service



Services: Same as Types 1 and 2.
Pressures: to 1200 psi.
Temperatures: —40°F to +250°F.
Construction Data: Heavy duty. Hydraulically balanced to handle high pressures. Single-unit package for easy installation.

TYPE 9
Sealing Members Made of Teflon* • Engineered for service conditions that do not permit use of rubber



Services: alkyl benzine, benzine, creosote, silicone oil, some petroleum derivatives, and all known corrosives.
Pressures: to 150 psi. (balanced construction to 750 psi.)
Temperatures: —120°F. to +500°F.
Construction Data: Furnished in the metallurgical specification best suited to the particular service. Flexible wedge ring and sealing ring molded from chemically inert Teflon.

Contact "John Crane" for the shaft seal best suited to your requirements. Request bulletin giving full information on "John Crane's" complete line of mechanical seals.

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Tennessee's Liquid Sulfur Dioxide, a product of highest purity, is particularly suitable as a solvent for recovery of aromatics—It is completely miscible with aromatic hydrocarbons over a wide temperature range, while the solubility of naphthene and paraffin hydrocarbons is limited and increases with decreasing temperature. Recovery of a higher percentage of aromatics is obtained for hydrocarbons over a wide boiling range.
Perhaps Tennessee's highest purity Liquid Sulfur Dioxide can effect a more efficient and economical operation in your processing. We would like to discuss these possibilities with you.
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• TON DRUMS
• TANK TRUCKS
• TANK CARS
TENNESSEE TC CORPORATION
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## Who's Building . . .

another 40,000 tons to the annual productivity, and thereby raise the total rated capacity to 190,000 tons a year.

**Ceylon's Minister of Industries** has just approved plans for an acetic acid plant which will produce 500 tons a year. The plant will also produce 250 tons of phenol, and 140 tons of methyl acetone annually. Cost of the new plant will be about $850,000.

**Laurentide Chemical & Sulphur Co.** has started construction on a $1.25 million plant at Montreal East for the manufacture of elemental sulphur from petroleum gases. This is the first such facility in Canada.

**British Petroleum (Kwinana), Ltd.,** will spend almost $8 million on a new expansion program at its 70,000 barrel a day refinery in Australia. The principal new processing unit to be added will be a 10,000 barrel a day Platformer. Additional storage will account for the remainder of the expenditure.

**Union Oil Company of California** will have its shale demonstration plant at Grand Valley, Colo., practically complete by the first of the year. Work is now being concentrated on installation of auxiliary equipment and assembly of the retort. The retort has a daily oil shale throughput of over 300 tons.

**Air Products, Inc.,** Allentown, Pa., has been awarded a contract by the Venezuelan government to design and build an air separation and air purification plant. The two plants, to be completed in 1957 at a cost of over $1 million, will be used to produce ammonia synthesis gas, and will be capable of producing 120 tons of ammonia daily.

**Humble Oil & Refining Co.** will build a benzene plant at its Baytown refinery. Construction will start this year, with completion scheduled near the end of 1957. The unit will be built as part of Humble's program of expansion in the petrochemicals field on a 40-acre tract of land owned by Humble.

The plant is designed to produce about 24 million gallons of benzene annually.

**Metal Hydrides, Inc.,** has authorized The Girdler Co., Louisville, Ky., to start engineering work on a hydrogen plant for its new facility at Danvers, Mass.

The hydrogen plant will employ propane as feed stock and produce hydrogen of 99.8% purity. Girdler catalysts will be used in the processing operation.

**Foster Wheeler Corp.** will build a lubricating oil manufacturing plant for Creole Petroleum Corp. at the Amuay Bay, Venezuela refinery.

A lube hydrofiner is one of several units to be installed in this major expansion program. Foster Wheeler will also design and construct a 75,000 bbl/day single-stage crude distillation unit which can be operated as a crude topping unit at a capacity of 110,000 bbl/day; a 17,000 bbl/day hydrofining unit for the desulfurization and general quality improvement of Diesel oil; a phenol extraction


For more data on advertising products, use Readers' Service Cards, last page.

# how would you like to add $250,000.00 to your profit?

***Dowell Chemical Cleaning Made This Possible for an Industrial Plant!***

In 1954 an East Coast plant employed Dowell Chemical Cleaning Service on a limited basis. The results were encouraging.

In 1955 the same company expanded its use of chemical cleaning. The results were startling. More throughput, less down time, and greater overall plant efficiency effected nearly a *$250,000.00 saving!*

In 1956 the program was continued. The result: still more savings. Eventually, chemical cleaning on a continuing year-around basis is expected to effect savings of from $300,000.00 to $500,000.00 annually.

This case history is about an oil refinery. However, Dowell has eye-opening performance data to show you in almost any industry.

Dowell engineers are experts in the use of solvents to remove scales and sludges—those deposits that cut the capacity of process and steam generating systems. Dowell does the job for you and furnishes all necessary chemicals, trained personnel, pumping and control equipment.

For additional information, call the Dowell office near you. Or write Dowell Incorporated, Tulsa 1, Oklahoma.

***clean it chemically*** **DOWELL**

A SUBSIDIARY OF THE DOW CHEMICAL COMPANY



For more data on advertising products, use Readers' Service Cards, last page.

exclusive
proven
construction

# Prevents Freezing of

## OCECO V-130 Conservation Regulators

**Positive flexing action of pliable cold and heat resistant membrane, held under tension, peels off icy formations without exceeding set pressures.**

***NEVER A REPORTED CASE OF VALVE FREEZE-UP***

Oceco V-130 Conservation Regulators bring never before secured economy and dependability to the conservation of volatile products stored in cone, round, flat, lifter or expansion roof tanks. Our exclusive pressure balanced construction prevents freeze-ups and protects the tank from excessive pressure and vacuum even under the most severe weather conditions. These regulators prevent vapors from escaping at less than operating setting and **provide greater flow capacity, size for size, and pressure for pressure,** especially at low pressures, **than ever before available.** Write for Bulletin No. 522. It gives full details!

**PRESSURE BALANCED CONSTRUCTION.** Tank pressures exerted on both sides of the pliable heat and cold resistant membrane keep membrane always under tension; —assuring tight seating fully up to operating setting— and positive flexing action that peels away icy formations preventing freeze-ups.

EXCLUSIVE OCECO FEATURE SAVES YOUR VAPOR DOLLARS!

**THE JOHNSTON & JENNINGS CO.**

**4700 West Division Street • Chicago 51, Illinois**

***Division of* PETTIBONE MULLIKEN CORPORATION**

## Who's Building . . .

unit; a propane dewaxing plant and complete blending, canning and packaging facilities for the various grades of lubricants.

**Koppers Company, Inc.,** will build a full-scale commercial plant for the production of expandable polystyrene beads. The new facilities will be constructed at Koppers large Kobuta, Pa., operation where the material has been produced in semi-commercial quantities since Koppers first announced its availability more than two years ago. Sold under the trade name Dylite expandable polystyrene, this material is produced in small beads which when heated in molds expands to take the shape of the enclosure.

**Carbide and Carbon Chemicals Co.** will build a new multi-million dollar engineering building in South Charleston, W. V. D. B. Benedict, president of Carbide and Carbon said the five-story structure will provide needed space for more than 500 engineers engaged in designing new equipment and new plants for the company.

**Union Carbide and Carbon Corp.** new petrochemical plant producing ethylene oxide, ethylene glucol, and polyethylene is now running at full scale in Torrance, Calif. The plant is located on a 140 acre site, and remains on stream 24 hours a day.

**E. I. du Pont de Nemours & Co.** is studying the possibility of increasing its methanol capacity by about 30 million gallons a year. Plans and estimates are being prepared for a "substantial increase" of methanol facilities at Sabine River Works, Orange, Texas. Present methanol capacity by du Pont is undisclosed.

**Industrial Asphalt Co.** will install four asphalt plants at various locations at a total cost of $600,000.

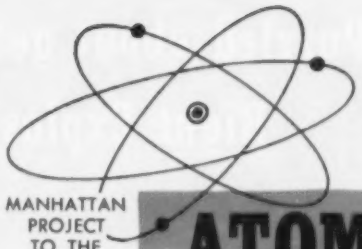
**British Geon,** a subsidiary of Distillers Company, Ltd., is in the process of building a synthetic rubber plant at Glamorganshire, adjacent to other plants in the Distillers plastics group. The new unit will produce butadiene-acrylonitrile copolymers.

**Irish Government** is still considering the possibility of constructing a refinery in northern Ireland. The Minister of Commerce, Lord Glenteran has told Parliament he is prepared to give full support to any proposal holding reasonable prospects of success. He also added that discussions with major oil companies had been going on for a long time but so far no definite proposals have been received.

Esso Petroleum, Caltex, Irish Shell and British Petroleum, Ltd., have already announced plans to establish a refinery in County Cork, Eire, with a capacity of 30,000 to 40,000 b/d.

**Wilshire Oil Co.** has lost interest in a Hawaii refinery, at least temporarily. After an on-the-spot investigation, unavailability of tankers was given as the reason.

**Wasag-Chemie, A. G.,** may choose somewhere in Texas as the site of their


CATAWISSA
PERFECT SEAL UNIONS
HAVE HAD A PART IN
EVERY APPLICATION OF

ATOMIC POWER

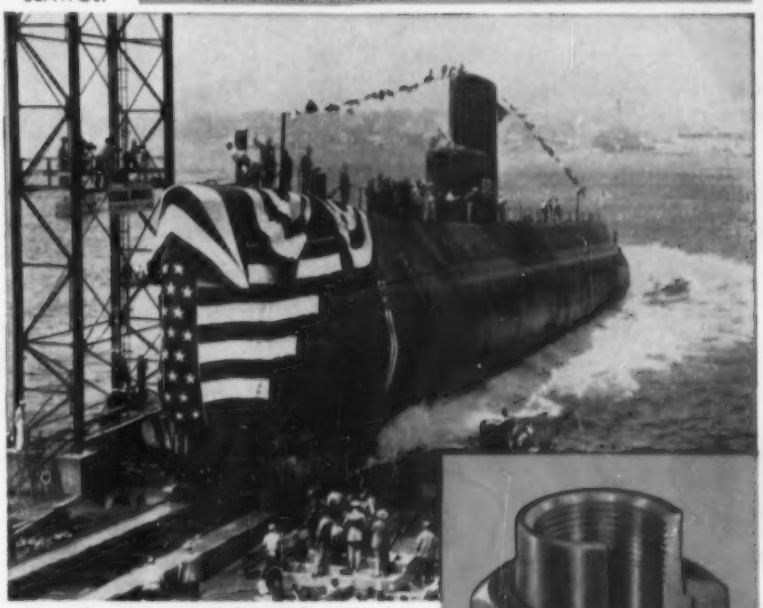


Photo courtesy of General Dynamics Corp.

LAUNCHING THE U.S.S. SEAWOLF at Groton, Conn., marked the development of the second atomic powered submarine built for the U.S. Government. Catawissa Valve & Fittings Co. is proud of its role in the project as major suppliers of Forged Steel Pipe Unions for the "Seawolf" — another repeat order in the atomic field . . . proof positive of satisfactory service!

SAFETY IS A "MUST"

From the original "Manhattan Project" to the U.S.S. Seawolf (and other unannounced atomic developments in private quarters), Catawissa Perfect Seal Pipe Unions have been specified to handle the extreme pressures involved. These are examples of "the toughest jobs", where absolute safety is a "must"!

3-TO-1 SAFETY FACTOR

One of the many extra value features of Catawissa Unions is in the very design itself — a design which gives each union a 3-to-1 safety factor. Catawissa 3000-lb. service unions, for example, are tested to 9000-lbs.; 6000-lb. service unions are tested to 18000-lbs., etc.

This point of superiority, plus expert workmanship and 40 years of experience, make Catawissa Forged Steel Pipe Unions and Swing Check Valves the best buy for rugged, trouble-free service wherever dependable performance is required.

PERFECT SEAL SEATING

Another Catawissa exclusive is its Ball-to-Angle seat design, which assures a Perfect Seal even when the two pipes joined are not in alignment.

ALL PRESSURES, TEMPERATURES

The Catawissa line is the most complete line of unions on the market—regular or special! They're hot forged from solid bars of AISI Spec. C-1026 steel, and meet the requirements of ASTM Spec. A-105, Grade 2.

YOU CAN TAKE THE GUESSWORK OUT OF PIPING PROBLEMS

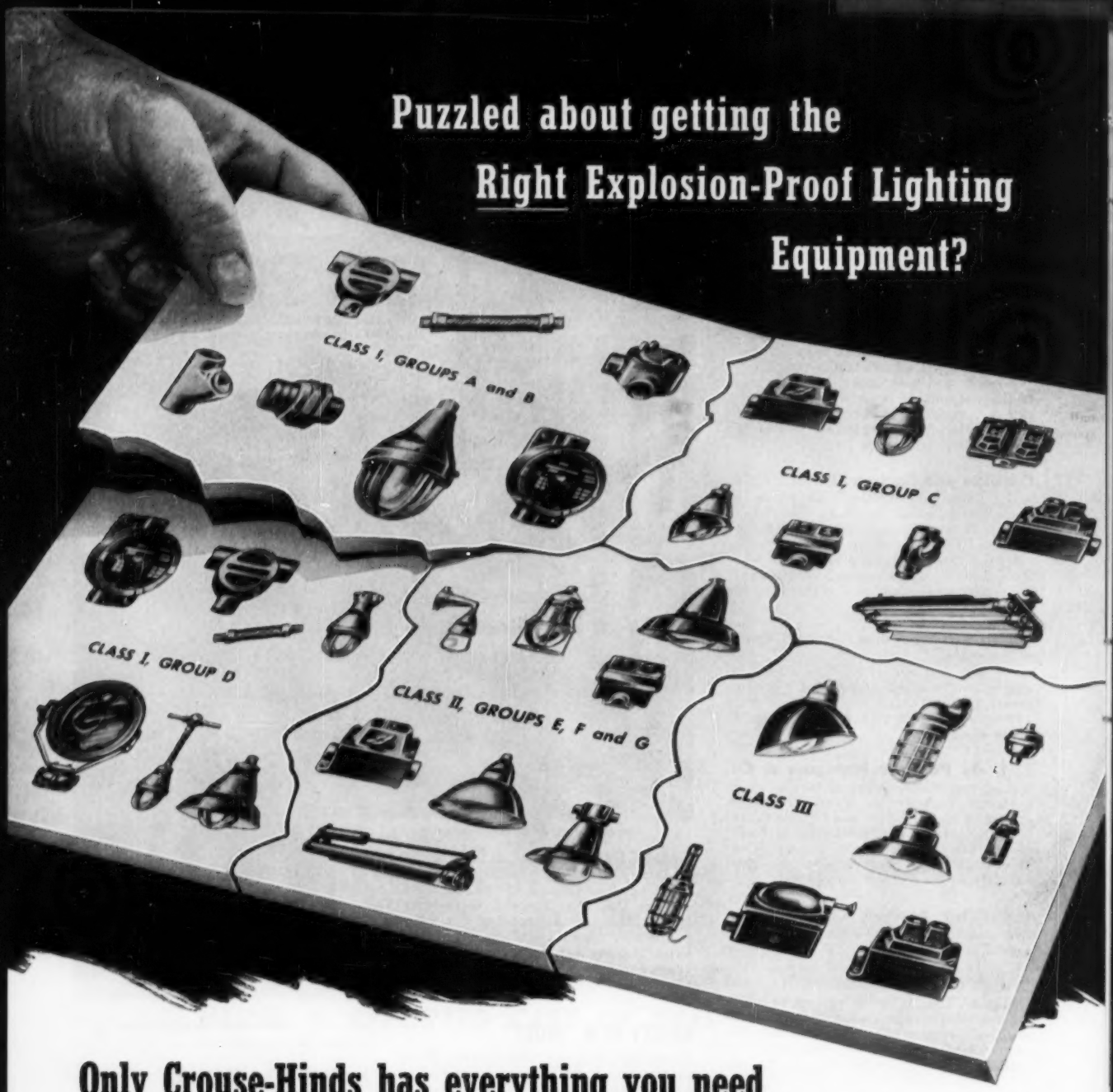
. . . specify CATAWISSA Perfect Seal Pipe Unions & Swing Check Valves • AT YOUR FAVORITE SUPPLY STORE •

CATAWISSA VALVE & FITTINGS CO.
CATAWISSA • PENNA.




For more data on advertised products, use Readers' Service Cards, last page.

# Puzzled about getting the Right Explosion-Proof Lighting Equipment?




## Only Crouse-Hinds has everything you need

### ...in every class ...in every group!

For *complete* protection when making lighting installations in hazardous locations you need more than explosion-proof or dust-tight lighting fixtures. You also need UL-listed explosion-proof switches, junctions, fixture supports, unions and seals.

Crouse-Hinds now offers a broad selection of Condulet* explosion-proof lighting equipment for Class I, Groups A and B locations. In fact, you can specify complete Crouse-Hinds explosion-proof lighting installations, all UL-listed, *no matter what class or group of Article 500 of the National Electrical Code is involved.*

The same holds true for the entire Crouse-Hinds Condulet line of more than 15,000 conventional and explosion-proof items. With the broadest line in the field, Crouse-Hinds recommends *exactly* what you need . . . and *only* what you need.

A nearby Crouse-Hinds distributor will be glad to discuss your explosion-proofing problems and make recommendations without obligation.

A NATIONWIDE DISTRIBUTION exclusively through ELECTRICAL DISTRIBUTORS

*Registered Trade-Mark

# CROUSE-HINDS COMPANY

Main Office and Factory: Syracuse, N. Y.
Crouse-Hinds Company of Canada, Ltd.: Toronto, Ont.

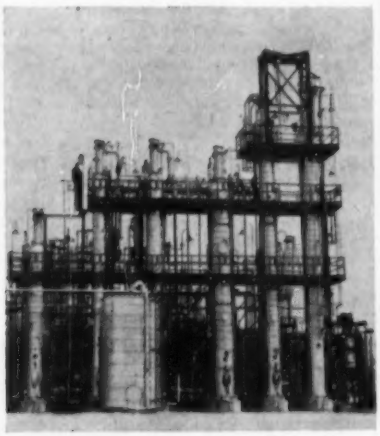
OFFICES: Birmingham Boston Buffalo Chicago Cincinnati Cleveland Corpus Christi Dallas Denver Detroit Houston Indianapolis Kansas City Los Angeles Milwaukee New Orleans New York Philadelphia Pittsburgh Portland, Ore. St. Louis St. Paul San Francisco Seattle Tulsa Washington RESIDENT REPRESENTATIVES Albany Atlanta Baltimore Baton Rouge Charlotte Chattanooga Jacksonville Reading, Pa. Richmond, Va. Shreveport

## Who's Building...

next plant. That is the indication following a visit by top officials of the German firm to the Houston area. They viewed plant sites in Texas City, Beaumont, Orange, Port Arthur, and Houston's ship channel. Wasag is a large munitions and plastics manufacturer in Germany, and has a technical information exchange agreement with Celanese.

**U. S. Industrial Chemicals Co.,** is studying a 50 million lbs./yr. plant to produce polyvinyl chloride and copolymer. U.S.I.C. is a division of National Distillers Products Corp.

**Celanese Corporation of America** has started construction of its new polyol unit at its chemical plant at Bishop, Texas. Utilizing a special aldoling process, the new facility is expected to be in operation by the last quarter of 1957.



**Petrochemicals From Kentucky—**

**Mono-, di-, and triethanolamines are produced from ammonia and ethylene oxide in this new unit at the Brandenburg, Kentucky, plant of Olin Mathieson Chemical Corp. Ethanolamines are used in the manufacture of detergents and as absorbents in gas-scrubbing operations. Ethylene oxide, ethylene glycol and related chemicals are produced elsewhere in the Brandenburg plant from natural gas obtained from the Tennessee Gas Transmission Co.'s trans-continental pipe line passing through western Kentucky.**

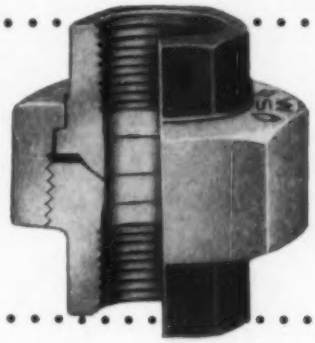
**Burma-Shell Oil Co.** has agreed to a government request to draw up plans for a 20,000 barrel a day refinery at Karachi. The Pakistan government is reportedly interested in contributing 25 percent of the $42 million cost of the new plant. At the present time Pakistan has only one small refinery which is owned by Attock Oil Company, at Rawalpindi.

**American Oil Co.** has awarded a multi-million-dollar contract to the Ralph M. Parsons Company, of Los Angeles, for the construction of a second 21,000-barrel-a-day ultraformer at its refinery in Texas City.

Engineering work already has been started and construction will begin in April, 1957. The ultraformer is scheduled to go on stream early in 1958. The Texas


# W-S FORGED STEEL UNIONS...

## These Features are YOUR GUARANTEE of a Safe, Tight Union Connection:



1. FORGED STEEL CONSTRUCTION— ASTM A-105, GRADE 2
2. SPHERICAL-TO-ANGLE MATING SURFACES
3. ANTI-GALLING, CADMIUM-PLATED NUTS

W-S Forged Steel Unions give you the kind of protection you need in high pressure piping systems. They're designed with precision-machined spherical-to-angle mating surfaces for positive seating, free from leaks even when pipes are slightly out of line. Cadmium-plated nuts resist galling and seizing and forged steel construction gives you the extra strength you need in high pressure service.

W-S Unions are available in 3000 lb. class, sizes ⅛" to 3" in screw-end and socket-welding types. Send today for your copy of Bulletin U-1.

*Sold Through Leading Distributors.*

W-S FITTINGS DIVISION

H. K. PORTER COMPANY, INC.

Roselle, New Jersey




For more data on advertising products, use Readers' Service Cards, last page.

# Verti-Line® Pumps

*offer your choice of column types*

Both types are precision made of the finest materials . . . And, feature after feature has been designed to make the Verti-Line Turbine Pump today's best buy in vertical pumps.

More than 100,000 satisfied vertical pump users agree there's no pump like Verti-Line for low first cost, economical operation, and negligible maintenance. Whatever your vertical pump needs may be, it will pay you to investigate Verti-Line before you buy.

Send for our new, 4-color, enlarged, sectional illustrations of both enclosed and open lineshaft pumps. Ask for Bulletin T-126.

*Verti-Line Pumps are the exclusive products of*

**LAYNE & BOWLER PUMP COMPANY**

***general offices and main plant***

2943 VAIL AVENUE • LOS ANGELES 22, CALIFORNIA

**LAYNE & BOWLER EXPORT CORPORATION** 650 South Grand Avenue, Los Angeles, a subsidiary


## Who's Building . . .

City refinery's first ultraformer was put into operation in February, 1955.

**The Fluor Corp., Ltd.,** Los Angeles, has been awarded a contract by The Texas Company for the engineering and construction of an 80,000 b/d vacuum pipe still at Port Arthur, Texas.

Engineering work will be performed at Fluor's Los Angeles headquarters. Construction is scheduled to begin in February, 1957, and completion is expected in December, 1957.

This new vacuum pipe still will replace existing units having a daily charge capacity of 60,000 barrels, resulting in a net increase of 20,000 barrels per day in the crude capacity of Texaco's Port Arthur refinery.

**Catalytic Construction Co.,** Philadelphia, has been awarded a contract for the engineering, procurement and construction of a new $2,000,000 Houdriformer unit for Texas City Refining, Inc., Texas City.

The new unit is expected to go on stream in about 10 months, assuming no materials restrictions because of world conditions. It will add 7000 barrels-per-day to the refinery capacity.

**Premier Oil Refining Co. of Texas** announced that Procon Incorporated, Des Plaines, Ill., has been awarded a contract to engineer and construct a 1500-barrel-per-day combination unifining-platforming unit at its refinery in Longview, Texas.

The Longview combination unit is scheduled for completion in April, 1957.

**The Vickers Petroleum Co., Inc.,** will construct a new million dollar ultraformer at its Potwin, Kansas, refinery, 35 miles northeast of Wichita. The unit was designed and engineered, and will be constructed by the Ralph M. Parsons Co. A tentative May completion objective has been set for the project.

The unit will supplement the T.C.C. unit which has been in operation at the Potwin refinery since 1953. Nominal capacity for the new ultraformer is expected to be 3500 barrels a day.

**Monsanto Chemical Co.** has disclosed plans for a major expansion of its production capacity for phenol. The company will invest several million dollars in additional production facilities for phenol at its Monsanto, Ill., plant.

The expansion, scheduled for completion in the second half of 1958, will boost Monsanto's phenol capacity by approximately 25 percent.

**Anderson-Prichard Oil Corp.,** Oklahoma City, has awarded a contract for the engineering, procurement, and construction of a 3000 b/d propane deasphalting unit to Badger Manufacturing Co., Cambridge, Mass. Work began at the Arkansas City, Kan., site on Oct. 8, and is expected to be completed late in 1957.

The process is said to be one of a new type and is licensed by Esso Research and Development Co.

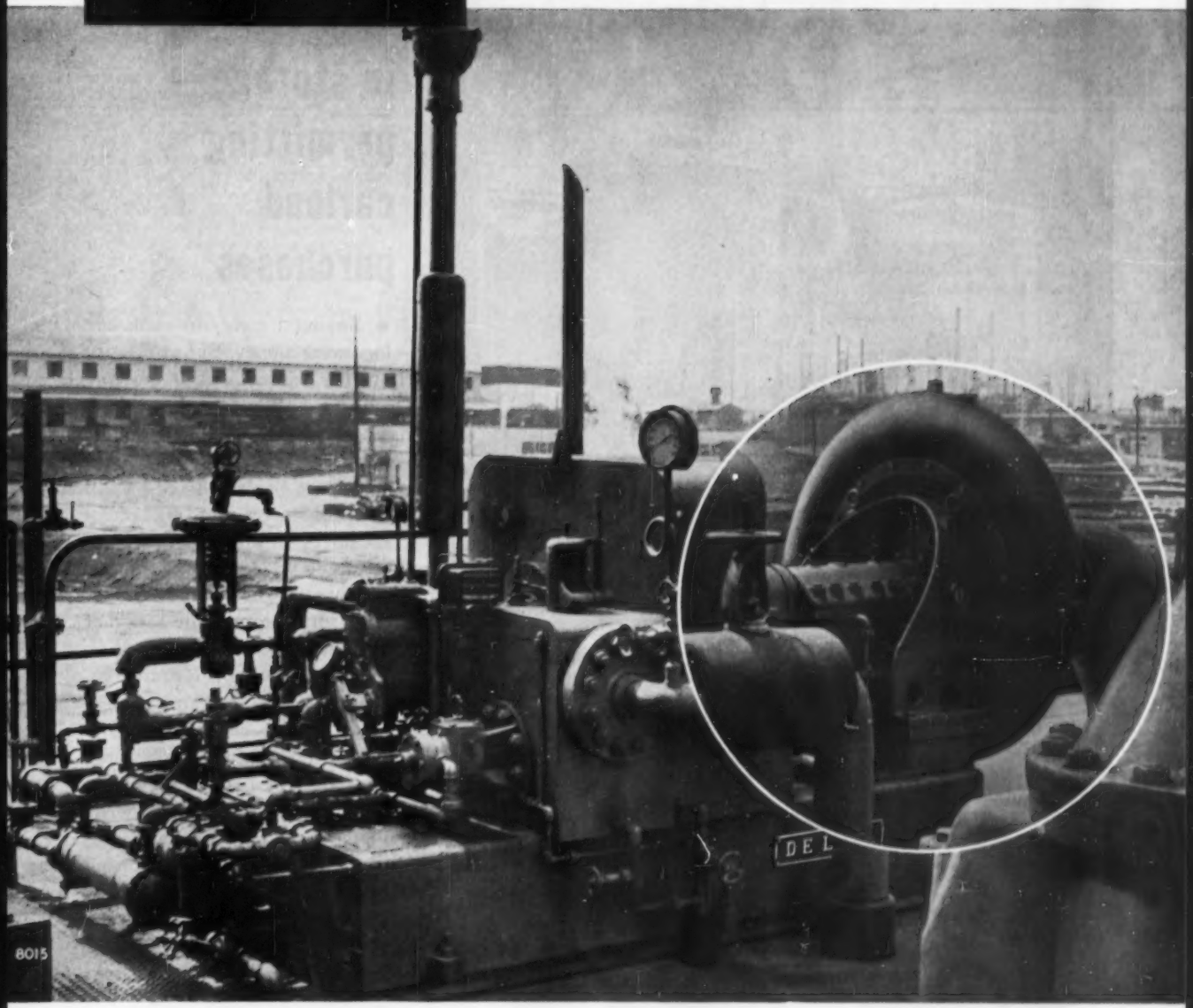
**Polymer Corporation** may build the million dollar synthetic rubber plant that is planned for Red Deer, mid-way between



For more data on advertised products, use Readers' Service Cards, last page.

# DE LAVAL
CENTRIFUGAL
BLOWER

## *controls air in cat cracker at Standard Oil of California*




This De Laval centrifugal blower, selected by the Fluor Corporation, is on stream at the Standard Oil Company of California's new cat cracker in El Segundo. For control air service, this blower delivers 9,500 cfm; inlet pressure is 15.4 psig and discharge pressure 19.4 psig. The blower is driven by a De Laval 220 brake horsepower MCP Turbine operating at 800 psig with a temperature of 650 F; it has all labyrinth shaft packing for high back pressure service.

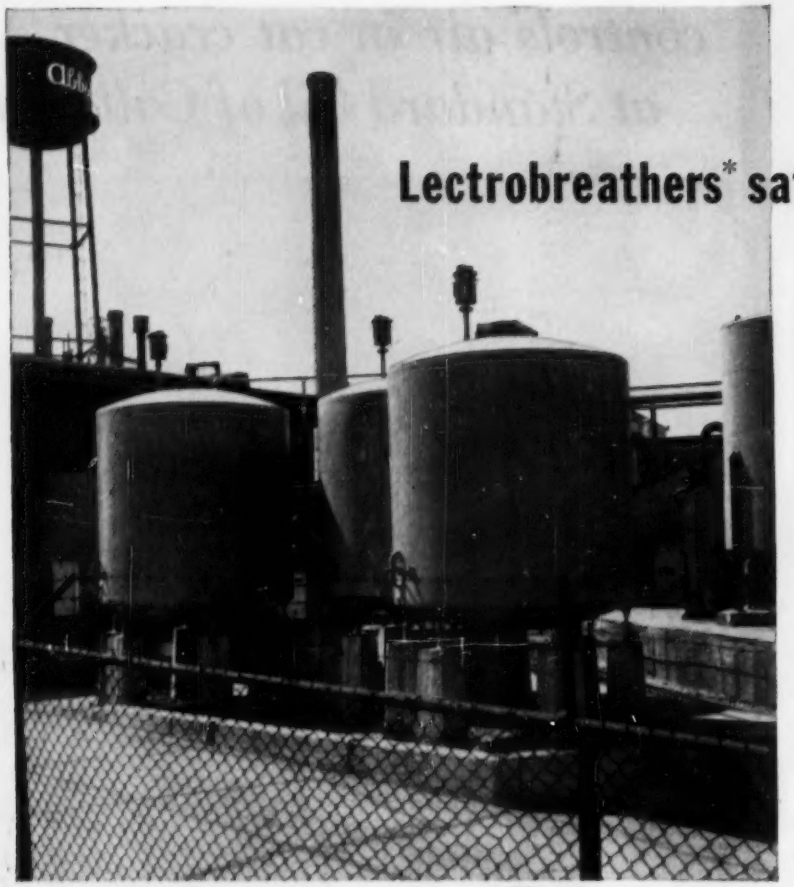
In addition to single stage designs, De Laval makes a complete line of equipment for all refinery services, including multi-stage compressors driven by De Laval multi-stage turbines for condensing, non-condensing and automatic extraction applications.

*Send for new Bulletin 0504*

**DE LAVAL** *Centrifugal Blowers*

DE LAVAL STEAM TURBINE COMPANY
*811 Nottingham Way, Trenton 2, New Jersey*

DL 509



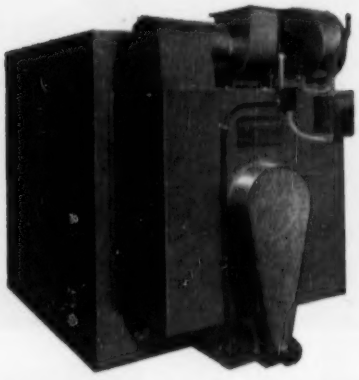
# Lectrobreathers* safeguard chemicals in storage—permitting carload purchases

● Buying liquids in tank car lots saves money. But profits are quickly washed out if storage tanks are allowed to inhale wet air as they breathe, contaminating their contents.

Abbott Laboratories solved this problem by installing Lectrobreathers on many of their outdoor and indoor storage tanks. Now, as pressures vary and those tanks draw in outside air, that air is DRY. The original high quality of their contents is preserved.

Lectrobreathers and Lectrodryers make certain that any tank, little or big, breathes only DRY air. For help in selecting the equipment you need, write Pittsburgh Lectrodryer Company, 307 32nd Street, Pittsburgh 30, Pennsylvania (a McGraw Electric Company Division).

*You see Lectrobreathers extending above tanks and rooftops at the Abbott Laboratories plant in North Chicago, Illinois.*



*Where volumes of air are large, as in a tank farm, a Lectrodryer* serves as a breather. Its DRYing-reactivation cycle is continual, so it stays right on the job.*

◀ *A tank breathes freely as air passes through the Activated Alumina adsorbent and is dried DRY. When a Lectrobreather needs reactivation, it is lifted off and a spare takes its place.*

In England: Birlec, Limited, Tyburn Road, Erdington, Birmingham.
In France: Stein et Roubaix, 24 Rue Erlanger, Paris XVI.
In Belgium: S. A. Belge Stein et Roubaix, 320 Rue du Moulin, Bressoux-Liege.

LECTRODRYERS DRY WITH ACTIVATED ALUMINAS

**LECTRODRYER**

*REGISTERED TRADEMARK U.S. PAT. OFF.

## Who's Building...

Calgary and Edmonton. The company has taken an option on 1100 acres of land 8 miles north of Red Deer.

**Refineria Panama S. A., and Refineria Y Petroquimica S. A.** have signed contracts with the Panamanian government to build two new refineries. Neither plant may be built in Colon, Panama City, or the Canal Free Zone, and refining must not start any later than August 6, 1960.

Refineria Panama S.A. (Panama Refining Co.), has bought about 2000 acres of land in Las Minas, extending up to Las Minas Bay and also Payardi. Size of the refinery has not yet been announced, but construction is due to start on the first of the year, after the rainy season is past. Refiineria Y Petroquimica (Panama Refinery and Petrochemical Co.), has not announced the location or the capacity of its plant.

**Petroleos Mexicanos** will build a lubricating grease plant and a 1000 b/d lubricating oil unit to operate on naphthene-base crude fractions, at Salamanca, Mexico. Both units will be completed sometime in 1958 at a cost of $4,500,000.

**Societe du Caoutchouc Butyl,** has awarded a contract to C. F. Braun & Co. for the general engineering of a synthetic rubber plant to be built in France. The plant will have a designed capacity of 20,000 tons of butyl rubber annually.

**Odessa Styrene Co.** will start construction in January on a new styrene plant at Odessa. The new plant will cost around $5 million, and at capacity operation will turn out 35 million pounds of styrene a year. Contract for construction has been let to Fish Engineering Corporation, Houston, and process design will be by Universal Oil Products. The plant is scheduled for completion by January, 1958.

**Turkish American Oil Co.** will commence construction shortly after the first of the year on its new refinery near Istanbul. Process units to be included in the new refinery are a 16,600 barrel atmospheric topping unit, a 6400 barrel crude vacuum unit, a 2400 barrel visbreaking unit, a 4900 barrel fluid catalytic cracking unit with complete gas recovery, a 480 barrel catalytic polymerization unit, and gasoline and kerosine treating facilities.

About two-thirds of Turkish American's total $18 million investment in the refinery is being supplied by private investors in the United States with the remainder being put up by private Turkish investors. M. W. Kellogg Co., New York, will handle engineering and construction of the new refinery.

**Indian Government** has set up a committee of 11 members to advise on the location of a new refinery with a projected capacity of 1½-2 million tons a year, based on crude oil from Assam fields. It is visualized that the State will have two-thirds control.

**Anderson-Prichard Oil Corp.** will expand its Arkansas City, Kans., refinery by 5000 barrels a day. A 2500 b/d crude


AVAILABLE FROM STOCK...

CAMCO

Light Weight

FORGED CARBON STEEL

BACK-UP FLANGES

FOR LOW PRESSURE SERVICE

*All surfaces protected with baked enamel finish.*

Our line of FORGED CARBON STEEL BACK-UP FLANGES have found wide acceptance in stainless and other alloy piping installations of lightwall pipe. (Schedules 5 & 10.) We believe the economy effected by their use warrants your consideration.

**For further details Ask for schedule FCS-856**

FREE!

CAMCO Products, Inc., 445 State Street CE
North Haven, Conn.

☐ Please send Flange Dimensional Slide Rule.
☐ Send literature covering complete line.
☐ Furnish address of area distributor.

Name_____

Company_____

Address_____

City_____ State_____

CAMCO PRODUCTS, INC.

**445 State Street North Haven, Conn.**




For more data on advertising products, use Readers' Service Cards, last page.

Wagner TRANSFORMERS...THE CHOICE OF LEADERS IN INDUSTRY

## Where uninterrupted power is a must...

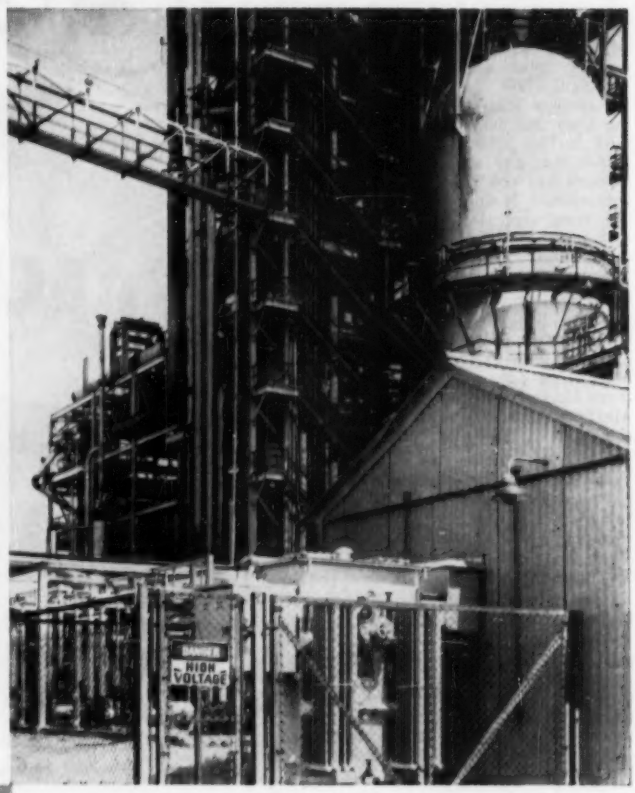
# WAGNER UNIT SUBSTATION TRANSFORMERS

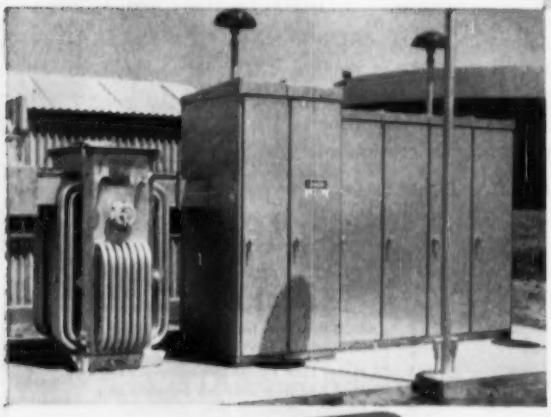
A completely dependable power supply is a vital necessity to an oil refinery. A power interruption of only a few minutes on a "cat cracker," like the one shown at the right, would completely disrupt this important processing operation and cause a shut-down of the entire refinery.

That's why you'll find Wagner Unit Substation Transformers at work at the Carter Oil Company refinery at Billings, Montana.

Wagner transformers are often found in installations where power supply failure would incur great loss because they have a reputation for complete dependability—backed by sixty-five years of transformer building experience.

Wagner Unit Substation Transformers, both liquid-filled and dry-type, are carefully designed to meet distribution requirements. Both liquid-filled and dry-type unit substation transformers are built in ratings through 2000 kva, 15 kv and below—you can choose the type and rating that exactly meets your load-center distribution requirements. Call the nearest of our 32 branch offices, or write us.



The 750 kva, 2400/4160Y to 480 volt, 60 cycle, three-phase, liquid-filled Wagner Unit Substation Transformer feeds the catalytic unit at The Carter Oil Company refinery. At left is shown a 225 kva Wagner substation transformer connected to an outdoor substation at the same refinery. Purchased and installed by The Fluor Corporation, Ltd., Engineers and Constructors for the Petroleum, Chemical and Power Industries, Los Angeles.

* * *

Write for Bulletins TU-205 and TU-214. They give full information on Wagner Unit Substation Transformers. Consult the nearest of our 32 branch offices about your next transformer installation.

Wagner Electric Corporation
EST. WE 1891

**Wagner Electric Corporation**
6457 Plymouth Ave., St. Louis 14, Mo., U.S.A.

BRANCHES AND DISTRIBUTORS IN ALL PRINCIPAL CITIES

*T56-9

ELECTRIC MOTORS • TRANSFORMERS • INDUSTRIAL BRAKES • AUTOMOTIVE BRAKE SYSTEMS—AIR AND HYDRAULIC

## Who's Building...

unit will be built to replace existing capacity, and the cat cracker will be expanded by 2500 barrels a day to handle 7500 barrels a day of charging stock.

**Petroquimica Cubana, S.A.,** will start construction before the end of the year on the first units of a $10 million petrochemical plant. The first unit of the seven year project will be a $7 million caustic soda, chlorine, and hydrogen plant.

**Carbide and Carbon Chemicals Co.** will spend $2 million more on air pollution equipment than is normally necessary at its ethylene chemical plant at Torrance, Calif.

**Foster Wheeler Corporation** will provide process and mechanical design, engineering and construction for the expansion program at the Port Neches Butadiene Plant of the Neches Butane Products Company. The plant, recently purchased from the government, is jointly owned by the Texas-U. S. Chemical Company and Goodrich-Gulf Chemicals Inc.

The present capacity of this plant, the largest in the world for the production of Butadiene, will be increased from 200,000 to 300,000 tons per year.

**El Paso Natural Gas Co.** has dropped its plans for a plant to process 20 million cubic feet of gas daily from South Andrews field, Andrews County, Texas. El Paso will still distribute the gas, but Shell Oil Co., has agreed to process it.

**Standard Oil Co. of California** is still planning a $30 million refinery at Honolulu Harbor mouth, but has been unable to proceed because of federal government delay in releasing the proposed site. Secretary of the Interior Fred Seaton has indicated that there may possibly be a decision by the end of the year.

**Commerce Oil Refining Corp.,** has received a fast tax amortization by the Office of Defense Mobilization for a $32 million plant at Jamestown, R. I.

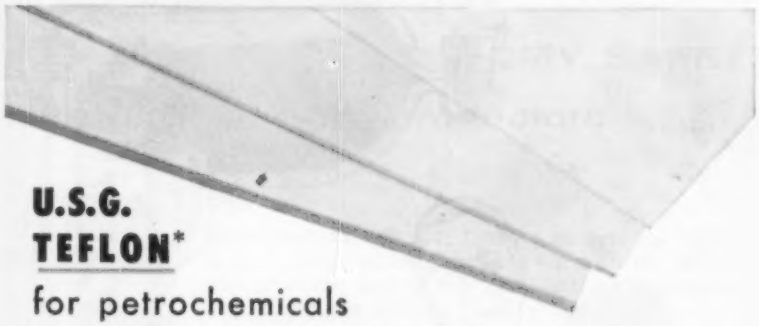
The projected 30,000 b/d plant was certified at 65 percent on $15,368,000, 40 percent on $15,743,500, and 15 percent on $855,000. Fast tax write-off was denied on $640,000 for land acquisition.

Commerce is an affiliate of Commerce Oil Corporation, Warren, Pa.

**Commercial Solvents Corp.,** and **Columbia Gas System** have agreed to make engineering and economic studies of a proposed joint project to turn out petroleum products.

The project, expected to involve an expenditure of between $40 million and $50 million for a plant located in the Ohio Valley area, has been under investigation for several months. Tentative plans call for construction to start early in 1957. The plant would use as raw materials the hydrocarbons extracted from Columbia Gas' natural gas reserves in the Appalachian area.

Plans call for a jointly-owned company which may engage in the production of ethylene, ethylene oxide, and other basic petroleum chemicals.

**U.S.G. TEFLON***

for petrochemicals

Inert to all chemicals (excepting molten alkali metals and fluorine at elevated temperatures). Available in sheets from ⅛" up. Also in cut gaskets to specification and in envelope gaskets with compressible filler materials for all standard pipe flanges.

Write for U.S.G. Bulletin No. 300 (sheets) or Bulletin TG-456 (Gaskets).

**United States Gasket Company**
Camden 1, New Jersey

here's the answer to sheet packing problems

**BELMONT NEOPRENE**

for oils and solvents

Belmont Neoprene sheet packing has high resistance to petroleum products, alcohol, caustics and many acids. It has high tensile strength and has good abrasion resistance.

Available in standard rolls, 40" wide by 10 yards long, in thicknesses from ⅛" to ¼" inc. and in durometer hardnesses of 40, 50, 60, 70, 80 and 90.

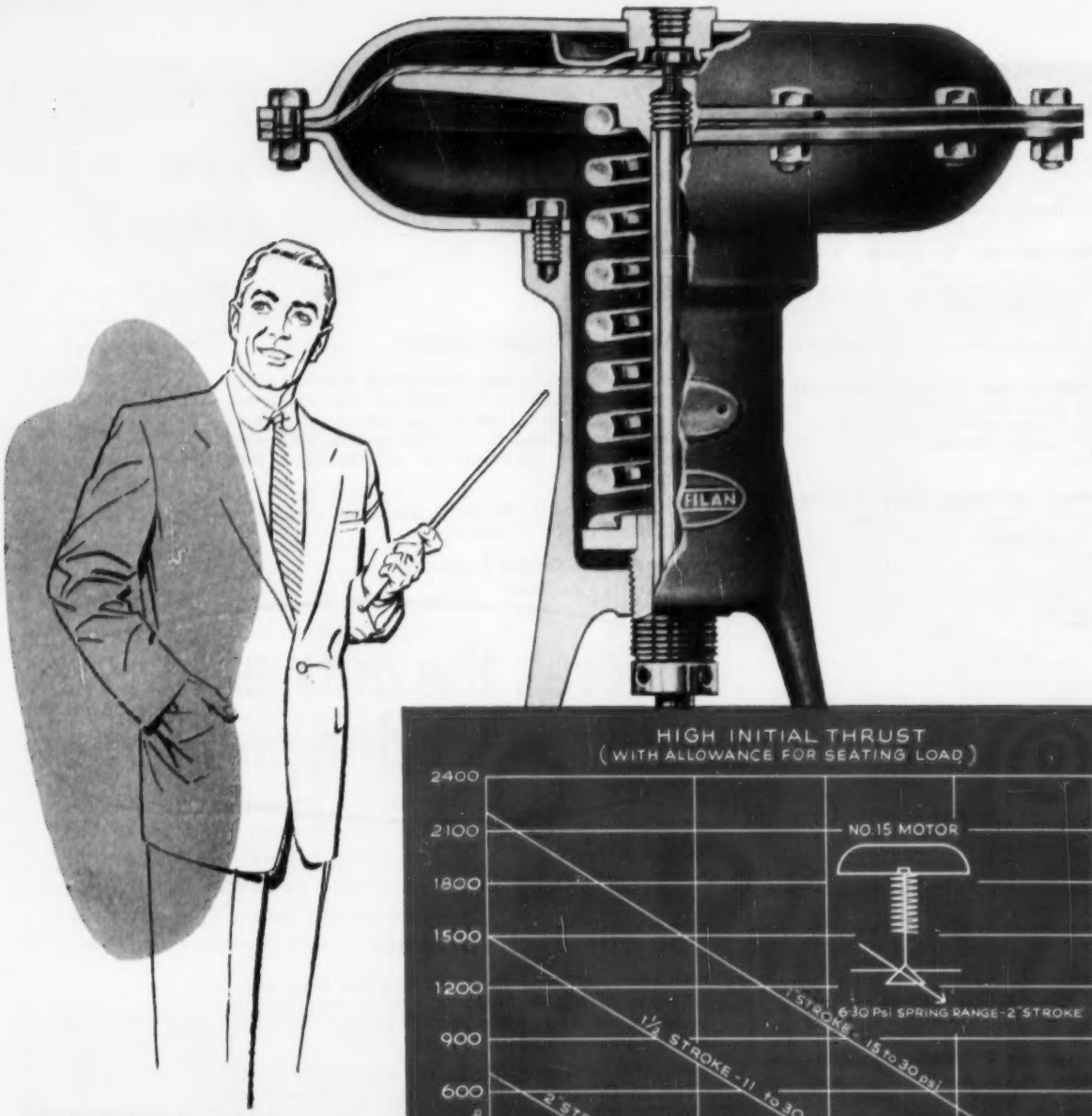
Also available in cut gaskets.

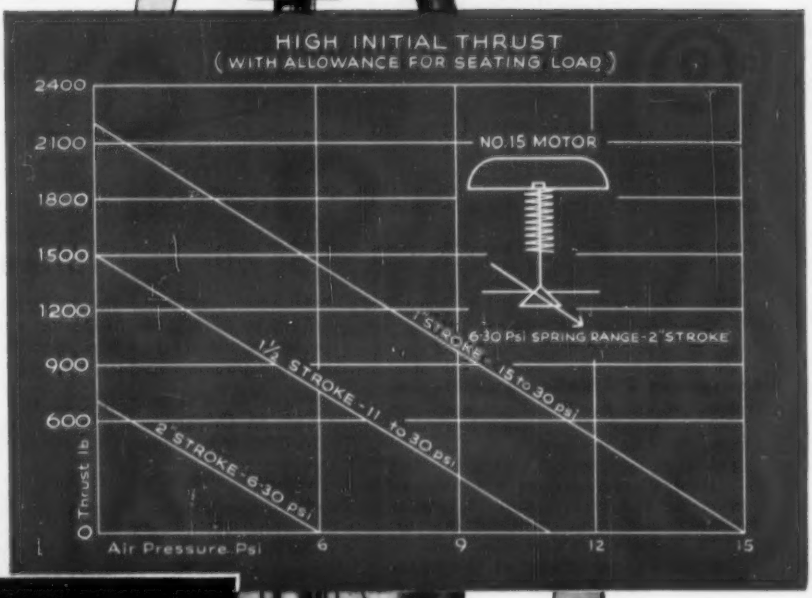
Write for Belmont Catalog No. 56.

**The Belmont Packing & Rubber Co.**
Butler & Sepviva Sts., Phila. 37, Pa.

**du Pont's trademark for its tetrafluoroethylene resin.*

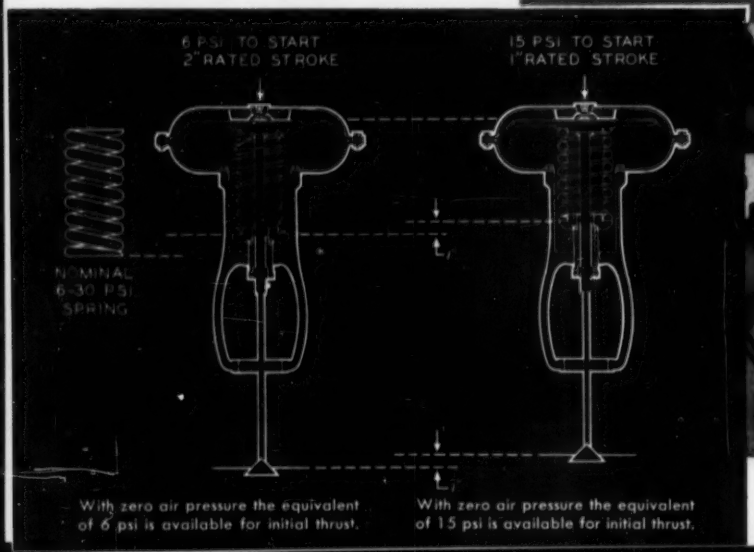
For more data on advertised products, use Readers' Service Cards, last page.

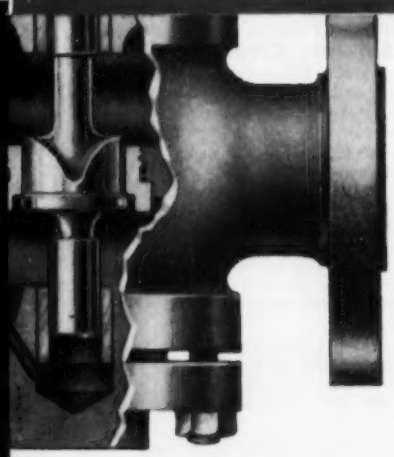



**HIGH INITIAL THRUST:**

**Example** — No. 15 Motor with 2" Rated Stroke and 6-30 psi Spring used on Valves with 2" and 1" Strokes.


6 PSI TO START
2" RATED STROKE
15 PSI TO START
1" RATED STROKE
NOMINAL
6-30 PSI
SPRING
With zero air pressure the equivalent of 6 psi is available for initial thrust.
With zero air pressure the equivalent of 15 psi is available for initial thrust.



# In Single Seated Control Valves

# Get AMPLE POWER plus SIMPLICITY, ECONOMY, SAFETY

# with Masoneilan Spring-diaphragm Motors

You get the best combination of safety (action on air failure) with maximum potential thrust, plus inherent simplicity and reliability in Masoneilan Spring-diaphragm Motors for single seated control valves.

Many single seated valves are specified to close on air failure. Hence the initial spring compression must provide the force for closing, since the valve would normally be installed with flow tending to open. Thus, to overcome unusual off-balance forces, a high *initial* thrust must be developed.

On air-to-close valves, the motor should develop a high net thrust at the *end* of the stroke. Thus, to overcome unusual off-balance forces a high *final* thrust is essential.

The design of Masoneilan motors enables you to obtain high *initial* thrust or high *final* thrust or, in the case of three-way valves, *both* high initial and final thrust, using, in most cases, standard springs.

Here's how —

**HIGH INITIAL THRUST:** Usually an oversize motor is used with a standard spring, but with the difference in stroke used to gain more initial compression and consequent additional spring force.

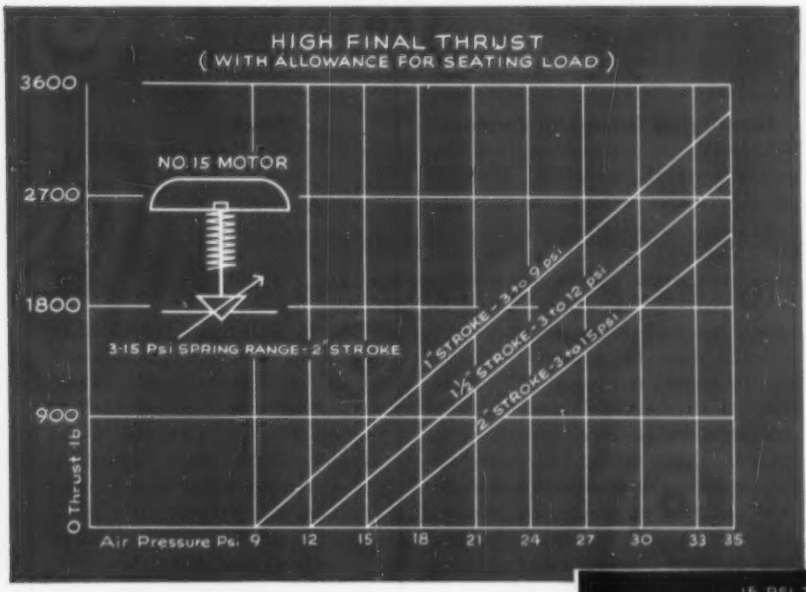
**HIGH FINAL THRUST:** The normal size motor often is used by simply increasing the air supply pressure to 30 or 35 psi. If necessary an oversize motor can be used to obtain even greater final net thrust.

**HIGH INITIAL AND FINAL THRUST:** Using an oversize motor permits adjusting the spring setting to obtain high initial thrust and makes an excess of supply pressure available for high final thrust.

**Example** — No. 18 Motor with 3½" Rated Stroke and 6-30 psi Spring used on Valve with 2" Stroke.

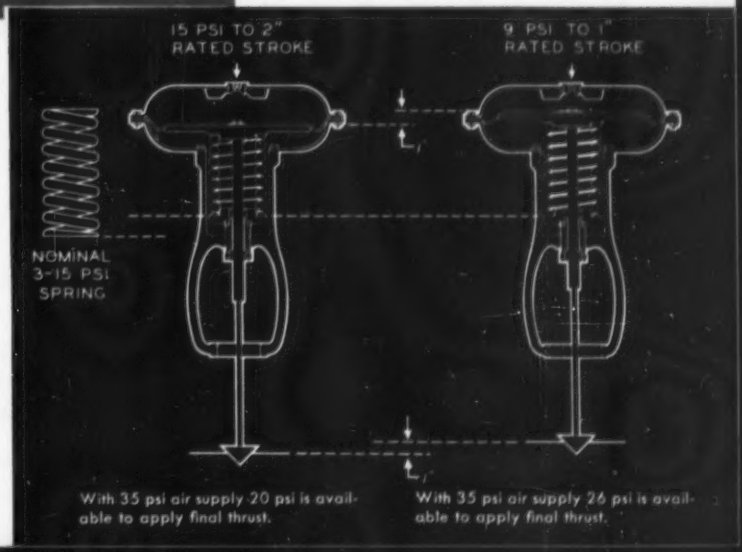
The spring can be set for 8-22 psi nominal range, giving an initial diaphragm load of 8 psi and (with 30 psi supply) 8 psi is also available for final thrust.

Tabulated data are available for facilitating correct control valve selection. Ask our nearest office for Data Sheet 10-11 — or write Mason-Neilan, Division of Worthington Corp., 51 Nahatan St., Norwood, Massachusetts.


HIGH FINAL THRUST
( WITH ALLOWANCE FOR SEATING LOAD )
3600
2700
1800
900
O Thrust lb
NO. 15 MOTOR
3-15 Psi SPRING RANGE - 2" STROKE
1" STROKE - 3 to 9 psi
1½" STROKE - 3 to 12 psi
2" STROKE - 3 to 15 psi
Air Pressure Psi 9 12 15 18 21 24 27 30 33 35

**HIGH FINAL THRUST:**

**Example** — No. 15 Motor with 2" Rated Stroke and 3-15 psi Spring used on Valves with 2" and 1" Strokes.


15 PSI TO 2" RATED STROKE
9 PSI TO 1" RATED STROKE
NOMINAL 3-15 PSI SPRING
With 35 psi air supply 20 psi is available to apply final thrust.
With 35 psi air supply 26 psi is available to apply final thrust.

# MASON-NEILAN

*Division of Worthington Corporation*

**51 Nahatan Street, Norwood, Massachusetts**

MASONEILAN

*Sales Offices or Distributors in the Following Cities:* New York • Syracuse Chicago • St. Louis • Tulsa • Philadelphia • Houston • Pittsburgh Atlanta • Cleveland • Cincinnati • Kansas City • Phoenix • Detroit San Francisco • Louisville • Salt Lake City • El Paso • Albuquerque Charlotte • Los Angeles • Corpus Christi • Denver • Appleton Birmingham • New Orleans • Seattle
Mason-Neilan Regulator Co., Ltd., Montreal and Toronto

# Need Craft Apprentices? Try Personnel Tests

**One major refinery is using personnel tests to select apprentices for eight crafts—with great success!**

**Robert E. Chandler**
Purdue University
Lafayette, Indiana

IF YOU HAD to select several men to enter apprenticeship in crafts working within your refinery, how would you go about it? Seniority or an interview might be your sole basis for selection. And, no doubt, if you had to cope with the problem tomorrow, some such basis would be the best available.

But a large refinery in the Midwest identified its personnel needs early in the game, introduced personnel tests to its employes, validated these tests, and is presently using them as an effective aid in the selection of apprentices into these eight crafts:

1. Electricians
2. Instrument Mechanics
3. Insulators
4. Sheet Metal Workers
5. Boilermakers
6. Machinists
7. Pipefitters
8. Welders

In the utilization of personnel tests for the selection of apprentices or any other employes, there is a rather well-defined procedure that one should pursue. In general, this procedure is centered around trying out, on present employes, tests which seem to offer promise. Of these tests, the ones that discriminate among these people can then be used in the selection of future employes. To be more specific, here is a detailed description of the approach that this company adopted.

**Choosing the Tests**—Executives of the company called in an industrial psychologist to assist them in determining a trial test battery. Company representatives discussed with the psychologist the type of work that was performed by men in each of the above crafts, because craft titles themselves can be misleading; e.g., pipefitters in a refinery may do work peculiar only to the petroleum industry.

After the crafts were examined rather thoroughly, the following tests were chosen to be tried out in each of the above crafts:

1. Bennett Test of Mechanical Comprehension
2. Purdue Adaptability Test
3. Purdue Industrial Mathematics Test

**Identifying Successful Employes**—Choosing an experimental test battery is merely the initial step in setting up a personnel testing program. The next, and highly important phase of the procedure, is to try out the tests to determine if they have any utility in the particular industrial setting in which you wish to use them. This is typically done by administering the tests to several employes, and identifying in this group those employes considered to be most successful on the job. The resulting test scores are then studied statistically to see if the most successful employes tend to score rather consistently higher on the tests than do those men regarded as being poorer performers on the job.

But what measures of job success can be employed to identify the successful employes? Some of the measures which have been used in many companies as criteria in test validation are:

- Job tenure
- Absenteeism
- Units produced
- Time required to meet a standard in job performance
- Rework time
- Performance in a training program
- Ratings by supervisors

Selection of one or more criteria is management's prerogative. The management of the refinery in which this study was conducted proposed the last two criteria listed above.

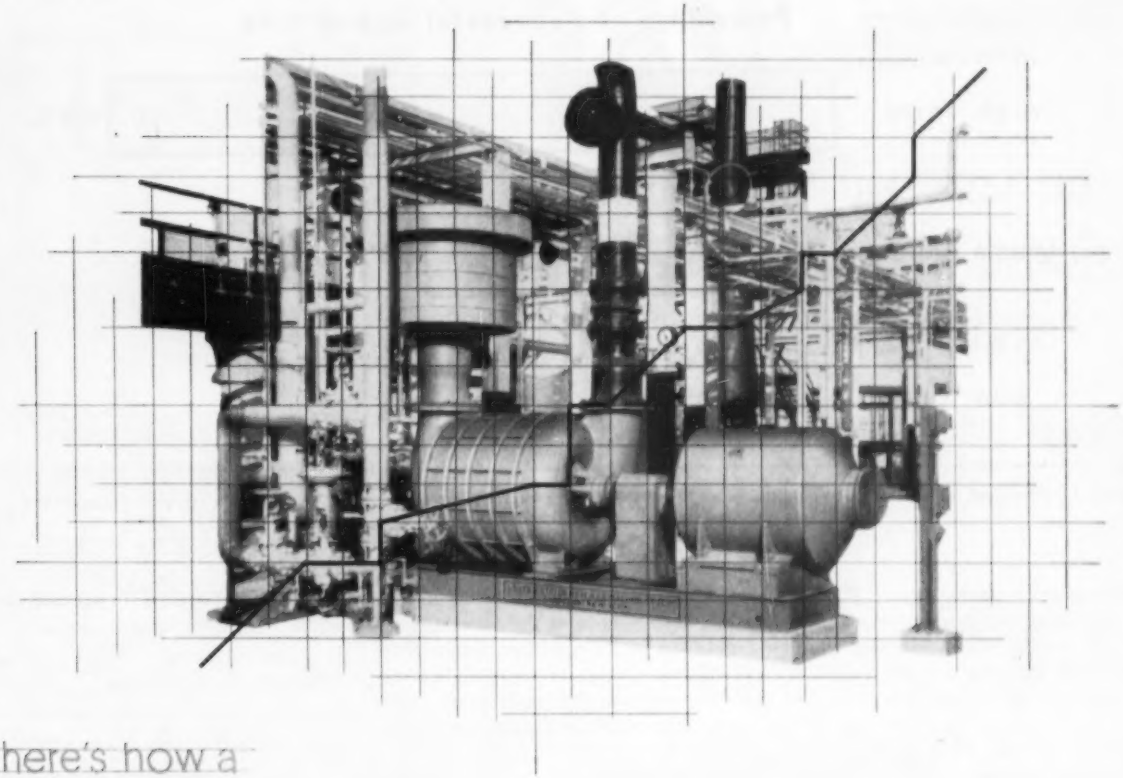
At the time the testing program was being established, about 350 men, who were already participating in the company apprentice training program,

**Meet the Author**

DR. ROBERT E. CHANDLER is Senior research psychologist with the Engineering Mechanics department of General Motors Corporation, Detroit, Mich. Prior to this he spent 18 months as a personnel specialist in the Air Force, one year as a staff member of Southern Illinois University, and three years as a staff member of Purdue University. It was while he was doing work at the Occupational Research Center at Purdue that Dr. Chandler wrote this paper.

Dr. Chandler holds a B.S. degree in mathematics, and a M.S. degree in guidance and consulting from Southern Illinois University. He also holds a Ph.D., in industrial psychology from Purdue University. He is a member of the American Psychology Association, Midwest Psychology Association, and Sigma Xi.

Hoffman engineered systems get **results:**



here's how a

## HOFFMAN MULTISTAGE CENTRIFUGAL BLOWER

helps recover valuable sulphur from refinery gas†

The by-product sulphur recovery system of a leading West Coast refinery required an unfailing, 24-hour-a-day source of process air.

Hoffman engineers, in conjunction with the refinery's consultants and engineering personnel, developed an unusual design to serve as the "heart" of the process.

A Hoffman multistage, centrifugal blower was direct-connected to dual drives with a steam turbine on one end and a 150 h.p. electric motor on the other. In the event of power or steam failure, the load can be automatically transferred from the motor to the turbine. The out-of-doors, all-weather installation thus functions continuously, dependably.

Here is yet another example of how Hoffman air appliance engineers work in conjunction with plant engineers, to design a "custom" installation. Find out how Hoffman engineered systems can get results for **you!** Write for free bulletin M-133.

AIR APPLIANCE DIVISION **U.S. HOFFMAN MACHINERY CORPORATION** DEPT. P.R.R., 103 FOURTH AVENUE, NEW YORK 3, N. Y.

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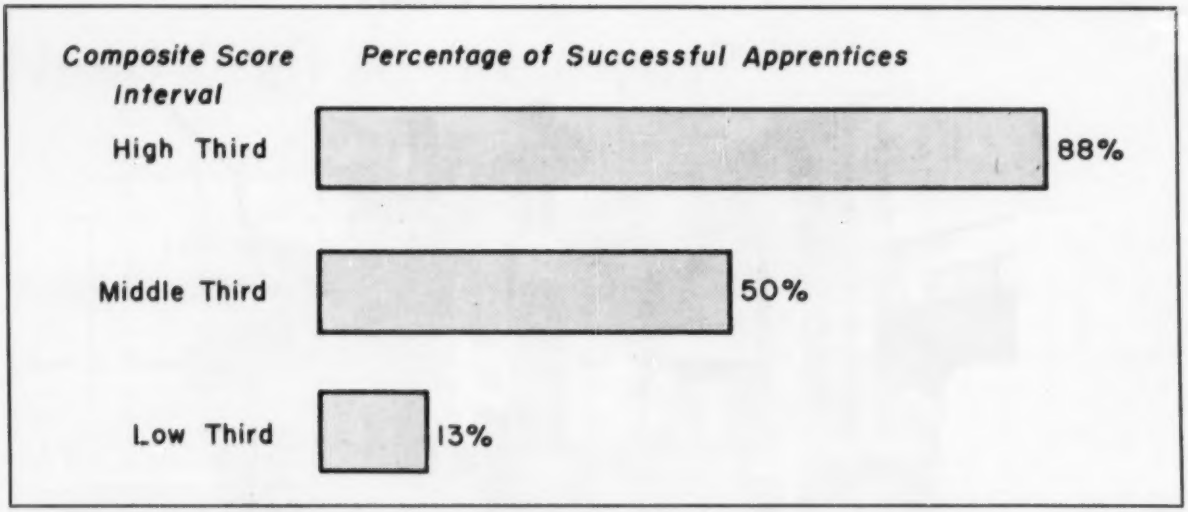



FIGURE 1—Percentage of successful apprentices in each composite score interval. The composite scores pertain to the electrical craft and were predicted from all three screening tests.

were available for this study. Early in the program, these men were administered the above test battery. They were told that the test results would be used in validating the tests and that their performance on the tests would in no way affect their completion of the program nor their ultimate job assignment. The test results were filed until the apprentices had completed the second year of their training. At that time, each apprentice had a cumulative training index which represented his performance on paper and pencil tests covering the content of the classroom lectures given in the program. This training index was used as one criterion.

The other criterion, supervisors' ratings, was developed after the apprentices had been given an opportunity to perform on the job. Supervisors of each of the crafts along with the head of the department to which these supervisors reported, rated each apprentice in their craft by classifying his over-all job performance into one of six categories.

With the development of these two criteria, a statistical analysis of the results of the tests was undertaken.

**Validation of Test Battery**—A validation process is typically a statistical problem which any professionally trained industrial psychologist can handle. In this particular study, tests found to be statistically related to either one or both of the criteria were combined in an equation designed to predict a composite score indicative of job success. For each craft these composite scores were graphically displayed in a manner similar to that shown in Figure 1.

This figure shows for each composite score bracket the percentage of men, within that bracket, who were regarded as successful apprentices. The extent to which the top bar in the graph is longer than the bottom one is representative of the benefit that can be obtained from using the tests employed in predicting the composite score.

Tests found applicable in one craft may not be in another. Because of this fact, Table 1 has been presented to summarize the findings of the statistical analysis.

**TABLE 1**
**Screening Tests Found to Be Useful for Apprentice Selection**

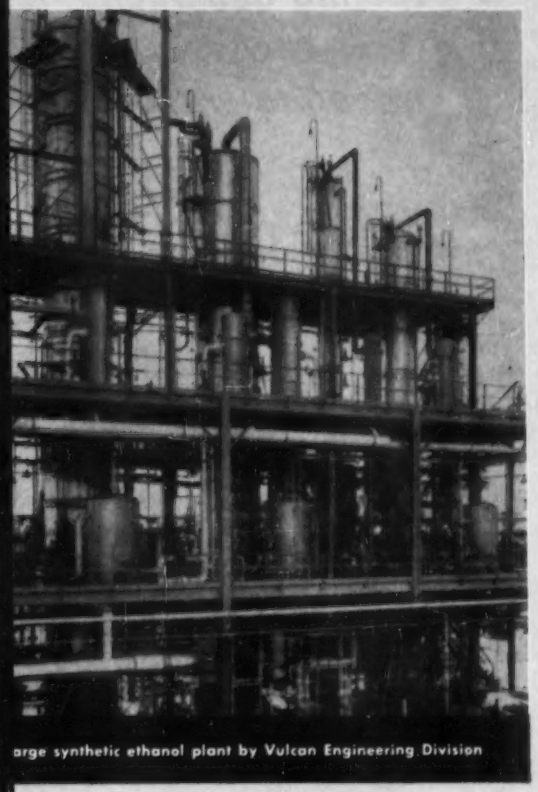
| CRAFT | TESTS FOUND USEFUL | | |
|---|---|---|---|
| | Mechanical Comprehension | Adaptability Test | Industrial Mathematics |
| Electricians | T, R* | T, R | R |
| Instrument Mechanics | R | R | T |
| Insulators | T | T | R |
| Sheet Metal Workers | .. | .. | .. |
| Boilermakers | T | .. | T |
| Machinists | .. | T | .. |
| Pipefitters | .. | T | T |
| Welders | .. | .. | .. |

* Indicates the criterion with which a test was found to be related. T represents the training index criterion, while R represents the rating criterion.

**Keeping Testing Program Dynamic**—Now that management has a statistical validated test battery to aid in the selection of future apprentices, the company is making every effort to keep the testing program dynamic. This includes explaining to the union the manner in which the battery will be used, the re-evaluation of the battery from time to time, and the addition of other tests to the battery—particularly for the two or three crafts in which the present tests were found to be of no value. Management intends to use the screening battery to supplement rather than supplant other selection methods. With this approach, the company is steadily improving the calibre of its apprentices and realizing all of the benefits associated with having superior craftsmen.

Your company can also receive the benefits of personnel testing. And such benefits are certainly not limited to the selection of apprentices, for tests have been used very successfully in the selection of clerical and other personnel. When you use personnel tests, always follow a procedure similar to the one discussed here. That is, never employ tests for selection without first trying them out and establishing their validity. Remember, tests found useful in the XYZ Company may be of no value to you! ##

# process know-how for . . . ETHANOL



arge synthetic ethanol plant by Vulcan Engineering Division

## *An important increase in ethanol production is predicted for the immediate future*

**WHAT PART WILL YOU HAVE IN THIS EXPANSION ?**

**VULCAN OFFERS YOU PROCESS EXPERIENCE FOR ETHANOL—**

- FERMENTATION
- SYNTHESIS
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Vulcan's accumulated experience with ethanol goes back over 55 years—covers hundreds of installations thruout this country and abroad —establishes Vulcan as the leading designer and constructor of plants for production and recovery of ethanol.

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ARMOR-PLATE structural steel, wire, pipe, fasteners and other metal items against rust with a tough zinc coating from the vats of the Nowery J. Smith Company. For the best in galvanizing service whether your job is routine or really rare, call the Nowery J. Smith Co. in Houston.

*Nowery J. Smith* COMPANY

Hempstead Hwy. at Eureka Underpass

*one of the* SMITH


## Operations Research . . .

*Continued from Page 128*

(4) must lie within (or on) the lines X, Y, and $\lambda_A$-and $\lambda_B$-axes. This area is shown hatched in the figure.

Of the possible programs there now remains to select the one (or those) that will give maximum profit. If P in equation (1) is a constant, the expression represents a straight line. To different profit values there corresponds a family of parallel straight lines, located so that the higher the value of P, the higher the corresponding line. This is illustrated by the lines $P_1$, $P_2$, and $P_3$ in the figure.

As shown, it is evident that the highest possible value of P is determined by "moving" a proft-line downward until it touches the nearest point of the hatched polygon. This determines the maximum profit as well as the manufacturing program (that is, $\lambda_A$ and $\lambda_B$) by which this profit is obtained.

Principle of the above method can be used on problems with any number of resources and products. Only the volume of computations limits the size of problem which can be handled. Similarly, the method can be used on problems of quite different appearances: Transportation problems, promotion problems, personnel assignment problems and inventory problems.

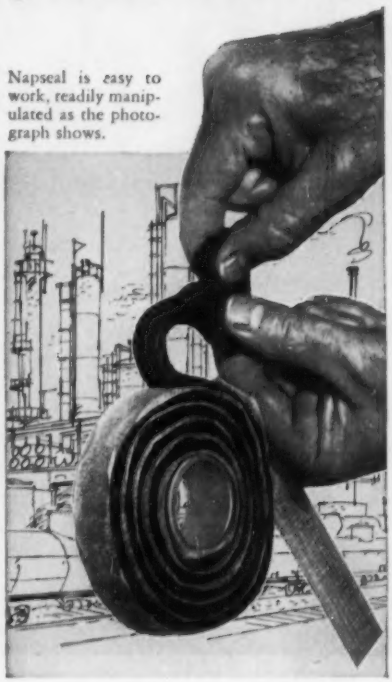
One early application was to the problem of gasoline blending in a refinery. This is described in detail in a paper by A. Charnes, W. W. Cooper and B. Mellon.[7] The following exposition is based on their paper.

Objective was to determine an optimum program for blending of straight-run gasolines, catalytically cracked gasoline, and certain chemical additives into aviation gasolines and premium automotive gasolines of given specifications. Basis for using the linear programming technique is that the desired specifications can be considered linear combinations of those of the components in the blend.

The study deals with a case in which four types of gasolines are to be blended from input components. The specified properties are performance numbers (P.N.) and Reid Vapor Pressure. The number of variables to be considered was limited by the fact that no high-speed computing equipment was to be used. Refinery policy dictated that the input components be


**NEW** *sealing compound resists gasoline and oil...*

Napseal is easy to work, readily manipulated as the photograph shows.



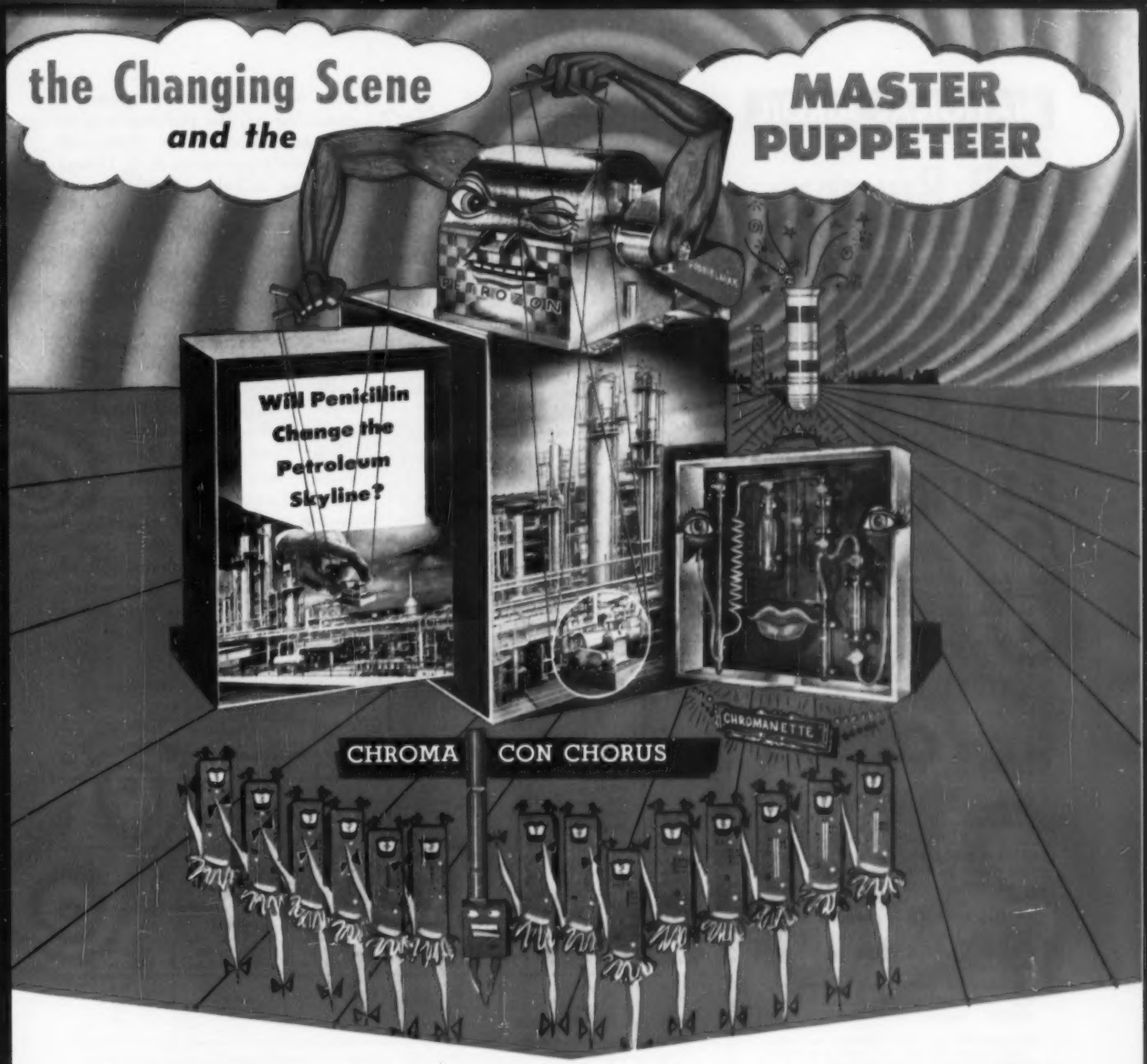
**J-M NAPSEAL**

Napseal is the compound for those difficult sealing jobs where exposure to oils and fuels (including aviation gasoline) is encountered. Highly adhesive, it holds a tight seal, remaining permanently plastic in the presence of petroleum derivatives. Napseal retains its water tightness, will not dry out in service.

Napseal is easy to work and remains workable over a wide temperature range. It will not corrode metals or cause the deterioration of common substances in contact. Neither will it stain.

Napseal is handy for emergencies and other sealing needs. It requires no mixing, comes ready to use in beads, ribbons and 3" diameter pugs. Data sheet EL-64A gives more information. Write Johns-Manville, Box 14, New York 16, N. Y. In Canada, Port Credit, Ontario.

**Johns-Manville SEALING COMPOUNDS**




TRENDS IN TECHNOLOGY — *Signposts* of the future are significantly portrayed in an article* appearing in the November 10 issue of "This Week In Chicago" reviewing techniques invaluable to the future progress of the petroleum and allied industries. The "changing scene" above symbolically panoramas the **NEW** LOOK.

IN THE PLANT!—PODBIELNIAK CENTRIFUGAL CONTACTORS AND SOLVENT EXTRACTORS are becoming a dominant factor in processing applications.

IN THE LABORATORY! — A new science of GAS TECHNOGOMY (Rip Van Winkling since Twsett, Martin and Synge) exemplified in such characterizations as the 14 Chromacon Chorus can "Analyze Almost Anything Accurately" from hydrogen to lubricating oils.

The CHROMANETTE, recently introduced, created a sensation! The natural gas and gasoline industry is realizing, with a staggering impact, that these new techniques represent a death knell to many oil industry standardization procedures. Empirical testing is on the run! — analytical results are quickly and accurately obtained out of a "suitcase type" apparatus available in attractive similated leathers, red and brown crocodile or black lizard. "On the spot" analyses — in portable units — and continuous Chromacon cyclic devices — for plant control are here!

CHROMANEER "packaged plants"— are industrial and pilot scale versions of the laboratory Chromacons and capable of producing rare products with *extreme* purity — more valuable than gold!

Great strides likewise are being made in competitive research programs through the aid of these miracle devices. These *"new tools"* have proven their merit and today are becoming a MUST in modern plants and laboratories. Many new products hitherto bound by conventional limitations are now unleashed in full force to enable the scientists of today to explore deep within the entrails of the *petrochemicals tree* and with Geiger Counter precision capture the heretofore captive mysteries of petroleum.

**This article and other literature available upon request, together with engineering questionnaire.*

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OF THE STEAM AND MECHANICAL TYPES NOW COMBINED INTO

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Now, at last, the inherent advantages of *both* systems of fuel oil atomization are *profitably* yours . . . within the one, new NATIONAL AIROIL Dual Stage Burner.

44 years of combustion equipment design and manufacture are in back of the Dual Stage Oil Burner . . . and, it has been thoroughly tested and proved in the field for firing: Petroleum Processing Heaters; Rotary Kilns; H.R.T., Scotch Marine and Water Tube Boilers; etc.

Available in three sizes, the NATIONAL AIROIL Dual Stage Burner fires all grades of fuel oil from No. 2 to No. 6, with a ready capacity of 80 to 300 g.p.h. Further, for a perfect flame pattern, we would recommend using with the Dual Stage Burner either the NATIONAL AIROIL Universal Register for forced draft or the NATIONAL AIROIL Tandem Unit for natural or induced draft furnaces.

Get detailed description, illustration, and specifications in NATIONAL AIROIL Bulletin 25.

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AUTOMATIC OIL BURNERS, for small process furnaces and heating plants
GAS BURNERS
COMBINATION GAS & OIL BURNERS
FUEL OIL PUMPING AND HEATING UNITS
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Established 1912 — Incorporated 1917

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1254 E. Sedgley Ave., Philadelphia 34, Pa.
S. W. Division: 2512 So. Blvd., Houston 6, Texas

## As Management Sees It . . .

used at given rates to eliminate need for additional tankage for these stocks.

The input components, their specifications and rates are listed in Table 1. Blended products and their specifications are listed in Table 2. The tables refer to two test conditions, 1-c and 3-c, which correspond to a rich (take-off) and a lean (cruising) mixture, respectively. Throughout the problem it is assumed that the maximum amount of tetraethyl lead (TEL) is used.

The yardstick, or measure of effectiveness, to be used for judging the value of any blending program is total net receipts. These are obtained by using suitable market prices for each of the four blends M, N, Q, and Z, and subtracting cost of the TEL from gross receipts. All other costs are considered fixed, and hence of no influence on the blending program.

Summing up, the problem may be stated as follows: With given volumes of the input stocks A, B, D, and F (as listed in Table 1), find the optimum blending program for the products M, N, Q, and Z (as listed in Table 2); that is, the program which results in maximum net receipts.

The problem was formulated in exactly the same manner as the simple two-dimensional example. The blending problem as stated required 10 equations (or inequalities) in 22 unknowns. It was solved by means of the Simplex Method, a systematic procedure developed by G. B. Dantzig.[6]

Initially only test condition 1-c was imposed. Two independent optimum programs were found. They are listed in Tables 3 and 4. Any linear combination of these two programs will, of course, also be an optimum program. The solutions obtained were in agree-

**TABLE 1**
**Aviation Gasoline Stocks**

| Symbol | Component | Specified Usage Bbls/Day | R.V.P. | BLENDING INDICES | | |
|---|---|---|---|---|---|---|
| | | | | P.N., Test 1-c | | P.N., Test 3-c |
| | | | | TEL cc/gal =0.5 | =4.0 | =4.0 |
| A | Alkylate I | 3,800 | 5.0 | 94.0 | 107.5 | 148.0 |
| B | Cat. Gasoline A | 2,652 | 8.0 | 83.0 | 93.0 | 106.0 |
| D | Straight Run Gas A | 4,081 | 4.0 | 74.0 | 87.0 | 80.0 |
| F | Isopentane | 1,300 | 20.5 | 95.0 | 108.0 | 140.0 |

**TABLE 2**
**List of Products**

| GASOLINES | | SPECIFICATIONS | | | |
|---|---|---|---|---|---|
| Symbol | Aviation Grades | Maximum R.V.P. | Maximum P.N., Test 1-c | Minimum P.N., Test 3-c | Maximum TEL, cc/gal |
| M | 80L | 7.0 | 80.0 | .... | 0.5 |
| N | 91C | 7.0 | 91.0 | 96 | 4.0 |
| Q | 100C | 7.0 | 100.0 | 130 | 4.0 |
| Z | Premium Motor | *) | *) | *) | 3.0 |

*) No bearing on computation since this gasoline is blended to specifications with other components.

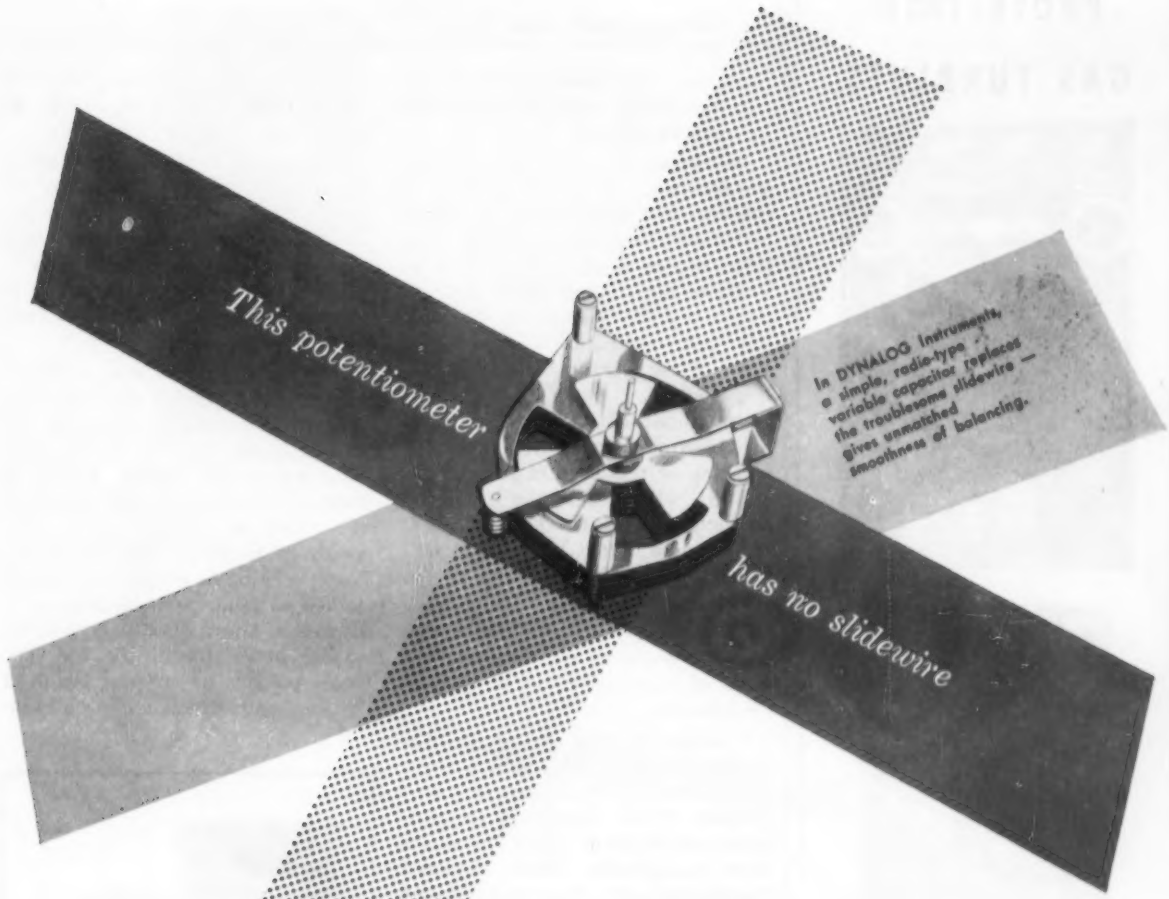
**TABLE 3**
**Inputs and Outputs (in Bbl/Day) for Optimum Program No. 1**

| Input \ Output | M | N | Q | Z | Total |
|---|---|---|---|---|---|
| A | .... | 60 | 3,740 | .... | 3,800 |
| B | .... | .... | 2,652 | .... | 2,652 |
| D | .... | 3,023 | 1,058 | .... | 4,081 |
| F | .... | 653 | 534 | 113 | 1,300 |
| Total | .... | 3,736 | 7,984 | 113 | 11,833 |

**TABLE 4**
**Inputs and Outputs (in Bbl/Day) for Optimum Program No. 2**

| Input \ Output | M | N | Q | Z | Total |
|---|---|---|---|---|---|
| A | .... | .... | 3,800 | .... | 3,800 |
| B | .... | 1,279 | 1,373 | .... | 2,652 |
| D | .... | 2,111 | 1,970 | .... | 4,081 |
| F | .... | 347 | 840 | 113 | 1,300 |
| Total | .... | 3,737 | 7,983 | 113 | 11,833 |


For more data on advertised products, use Readers' Service Cards, last page.


This potentiometer
has no slidewire
In DYNALOG instruments, a simple, radio-type variable capacitor replaces the troublesome slidewire — gives unmatched smoothness of balancing.

## STEPLESS CAPACITY-BALANCING
# ELIMINATES STANDARDIZING!

**DYNALOG'S EXCLUSIVE BALANCING ACTION**

- no slidewire
- no batteries
- no standardizing
- no gears, cables, etc.
- no high-speed reversing motor

Here's the potentiometer that's *never* "off process" for standardizing. It requires none! The Dynalog's advanced, stepless-balancing design eliminates dry cell, provides *direct, uninterrupted* evaluation of the measured variable with sustained high accuracy.

Dynalog* design eliminates slidewire maintenance and motor servicing too! A simple, variable capacitor and positive magnetic drive provide smooth, continuous balancing action . . . instant response without wear. There are no fast-moving parts . . . no gears, cables, or complicated mechanisms. Only five moving parts, including the recording pen!

Dynalog Instruments are available for use with resistance, voltage, capacity, or inductive type primary elements to measure and/or control any process variable. For complete details, write for Bulletin 427. The Foxboro Company, 7412 Neponset Ave., Foxboro, Mass., U.S.A.

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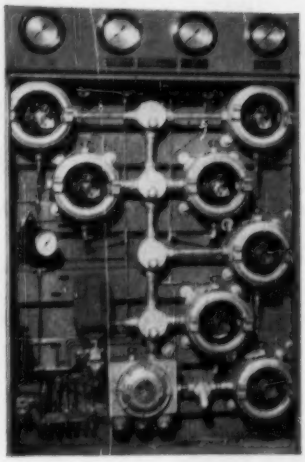
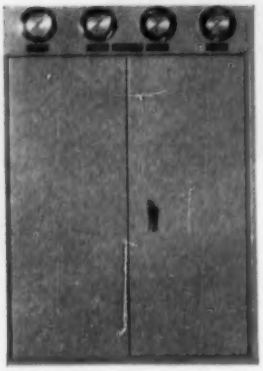
PROTECTION
for
GAS TURBINES





MERCOID
SAFETY CONTROL
PANELS

**Illustration above is a typical custom made explosion proof Mercoid Safety Control Panel which safeguards Gas Turbines by providing the following control functions:**

***Clutch pressure • High pressure lube oil • Axial compressor discharge • Bearing lube oil pressure • Fuel supply pressure • Overspeed pressure • Impeller pressure • Starting turbine throttle pressure • Lube oil high temperature • Exhaust temperature shutdown • Exhaust temperature alarm.***

**There are many more safety functions Mercoid can provide—our engineers will be pleased to offer their recommendations on the proper application of Mercoid Safety Controls for your gas turbines.**

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ment with independent program calculations for the same problems made by company officials.

As explained earlier, once set up, the mathematical model can be used for dry runs, determining the effects of various changes in conditions. This programming model was used to investigate the changes in net receipts produced by: (a) using the more strict test combination 1-c and 3-c instead of 1-c alone; (b) a policy requirement that exactly 500 bbl./day be produced of product M; (c) a policy requirement that at least 500 bbl./day be produced of product M; and (d) changes in the blending characteristics of the input, such as reduction of the R.V.P. and octane rating.

Likewise, the model could have been used to investigate the consequences of changing the fixed volumes of input stocks to be used in the blending.

Calculations show that some of the changes produce only slight changes in net receipts (but at times with considerable detail changes in the program), while others affect the net receipts considerably. These calculated changes were not always in agreement with those predicted by experienced company officials.

As the authors point out, this suggests that when conditions are stable, even under complex conditions, experience will give an optimum or near-optimum program; but when conditions change rapidly, cut-and-try methods likely are to depart considerably from optimum solutions. Thus the main advantages of linear programming lie not necessarily in the fact that it provides better solutions, but more in the fact that it provides a complete routine procedure which can investigate changing conditions rapidly, and which can be handled by less skilled personnel.

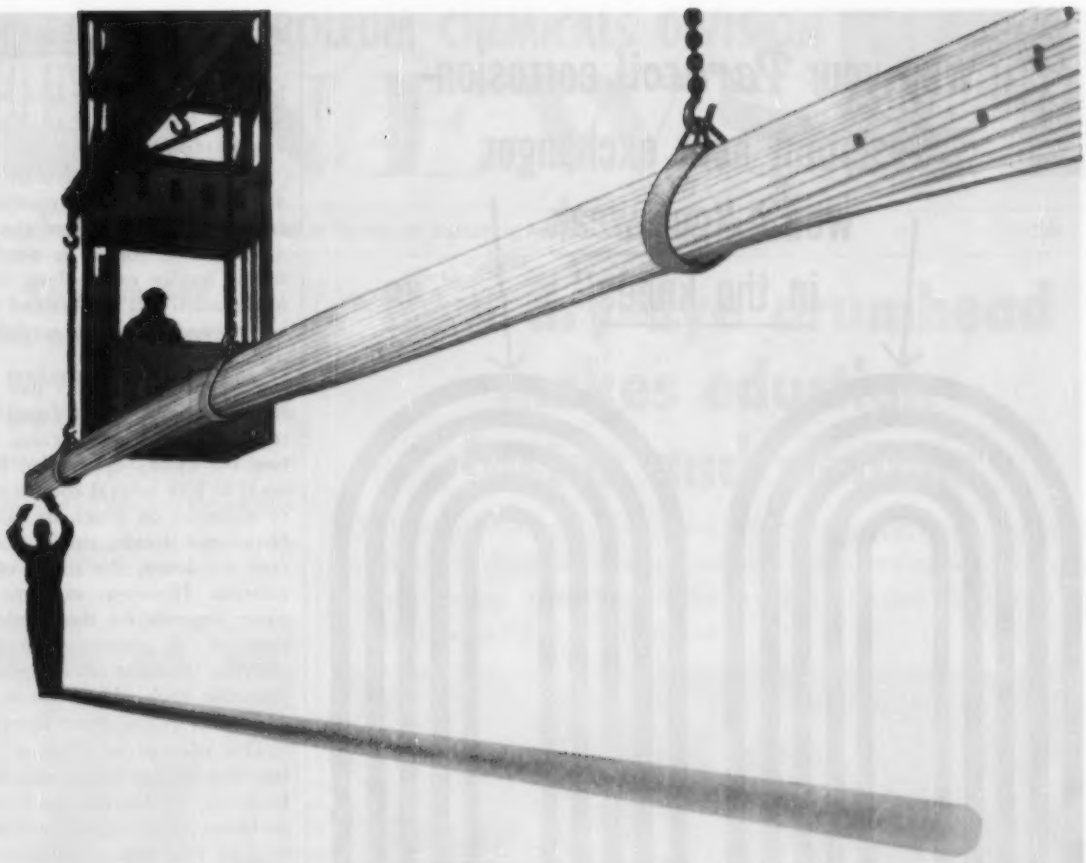
Linear programming, however, is but one of the mathematical disciplines which may be brought to bear on an operational problem. Others are applied statistics, perhaps the most important of all, and the related queueing theory and sampling theory; game theory, differential and integral calculus, symbolic logic, and Monte Carlo methods. In fact, any available analytical method will be used as the need arises.

The predominant position of statistics is perhaps a reflection of the unpredictable elements in human nature: Statistics is concerned with establishing which conclusions can be drawn when significant quantities of the problem are partly unknown (and perhaps unknowable).

An example of this is queueing theory, which predicts the characteristics of a queue or waiting line formed at some gate or service point when units (or persons) arrive in some statistical manner and are served at the gate in a known fashion. This occurs in many everyday affairs: People waiting in a cafeteria, aircraft stacked to land, parts waiting to be serviced in an overhaul shop, patients waiting to see the doctor, etc. The theory predicts the average length of the line, probabilities for given num-

**About the Author**

TAGE A. MORTENSEN, head of the Operations Research Section, Midwest Research Institute, holds two degrees, B.S.M.E., 1941, and M.S.M.E. 1945, from the Technical University of Denmark. He has had several years' experience in operations research, with inventory and scheduling applications his main interests. He also has worked in the fields of experimental acoustics and aerodynamics, optical instrumentation, and vibration measurement and analysis. Prior to joining Midwest Research Institute in 1947, he was research engineer in the Laboratory of Technical Physics at the Technical University of Denmark in Copenhagen.



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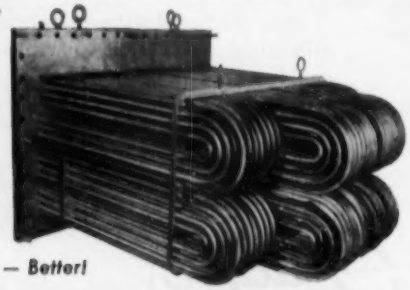

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## As Management Sees It...

bers of persons in the line, and probabilities for having to wait given lengths of time.

This theory is particularly important when the system is operating near capacity, that is, when the rate of arrival of customers is nearly equal to the service rate.[3] Here, important information can be obtained as to the best way of improving service and reducing queue length.

Another analytical tool is game theory. It is developed from the common-sense idea of a game between two (or more) opponents. Each has open to him several courses of action or strategies on which he can decide. He cannot decide, and in many cases does not know, the action of his opponents. However, outcome of the game depends on the combined actions of all players. The processes whereby the most advantageous strategies for each player are found are developed by the game theory.

This concept of a game has seen considerable use in the military field. However, in business and industrial problems, game theory methods have not, as yet, been extensively employed.

Monte Carlo techniques constitute a short-cut method for simulation of real-life events. When a mathematical model has been established, its input data, representing actual events, may be known to have certain statistical characteristics. While they can be obtained by observations (for example by counting the number of people arriving in a store or at a queue in given time intervals), it may be far easier to generate them artificially. The processes whereby this is done are called Monte Carlo methods. They are especially important where analytical solutions are not available for the mathematical model, which, consequently, must be examined by inserting numerous sets of data describing the event in question.

A tool which, in a sense, has grown up with operations research is the high-speed automatic computer. While it is true that it, in itself, merely adds muscles, making calculations faster, it is equally true that many of the analytical techniques would never have been used in practice without the aid of high-speed computing. Sheer bulk of calculations



For more data on advertised products, use Readers' Service Cards, last page.

PETROLEUM CHEMICALS DIVISION

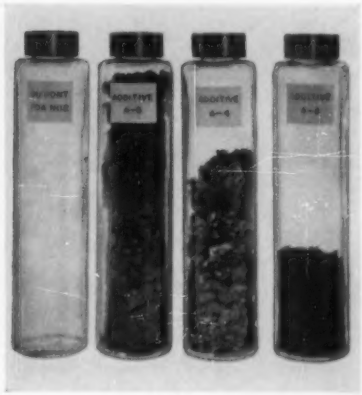
# NEWS

December ★ One of a Series of Bulletins for the Petroleum Industry ★ 1956

## You can SEE the advantage of using ASHLESS Du Pont FOA-2

When you burn 1,000 gallons of home heating oil containing a dispersant additive, how much ash does the additive leave?

That depends on the additive—as the picture below clearly shows.



These bottles (8 fluid-ounce size) contain the amount of ash left from burning four different heating oil additives.

The bottle on the left contains practically *no* ash, although enough *nonmetallic* Du Pont Fuel Oil Additive No. 2 (FOA-2) was burned to protect 1,000 gallons of fuel oil. (Actual concentration: 20 lbs./1,000 bbls.) The other bottles contain the ash left after burning cost-equivalent amounts of three metallic additives. The difference is so striking that comment seems superfluous.

### Stack control failures

What damage do these ash deposits do in the burner system?

Many stack control failures can be attributed to metallic ash deposits on the helical coil. And such failures are likely to prove hazardous and result in needless, unprofitable service calls.

In rotary burners, metallic additives leave deposits on the flame rim and electrode. These tend to short out the electrode, causing ignition difficulties. And even if ignition is accomplished, the deposits on the rim will interfere with the progress of the flame around it.

### In diesel fuels

When metallic additives are used to stabilize economy grade diesel fuels, there is a danger that these additives will contribute a sparking tendency to the fuel.

* * *

For more information about FOA-2, just address your request to our nearest sales office.

# New dry-dye drumhead makes eduction faster and cleaner

Du Pont petroleum dyes are now being shipped in drums covered with newly designed steel drumheads, each having a 2-inch circular opening. Through this the dry-dye eduction probe can be easily inserted and manipulated.

**NOTE HOW** easily the dry-dye eduction probe can be inserted through the opening of this new-type Du Pont dye drumhead.

This opening is sealed with a plastic disc. When the dye is to be removed, the disc can be easily cut out with a penknife. (See cut on next page.)

The opening is rimmed with plastic which is threaded to accommodate a standard 2-inch pipe plug. That means easy re-sealing . . . to protect the quality which is built into all Du Pont dyes.

The new drumhead need not be removed. Using the small opening instead reduces dusting to an absolute minimum. When the eduction probe is inserted, little open space is left around it. Hence little, if any, dry dye will

ADVERTISEMENT—Prepared for the Petroleum Chemicals Division of E. I. du Pont de Nemours & Company (Inc.)

OVER

DU PONT

# PETROLEUM CHEMICALS DIVISION NEWS

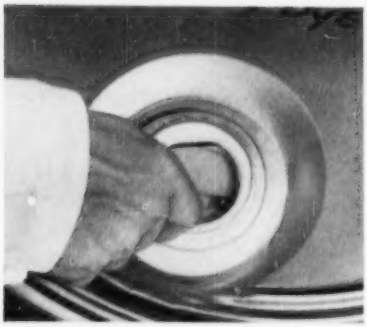
DU PONT

**CONTINUED** *New dye drum*

emerge, except as desired—through the probe itself.

**Second recent improvement**

The new drumhead follows by only six months another radical improvement in dry-dye eduction procedure—the new probe that is virtually clog-proof. More than 100 are now in service, and the demand for them continues.



**FOR SHIPPING,** the small opening is sealed with a plastic disc which can be easily cut out with a pocket knife.

Any of our sales offices listed below will be glad to give you complete information on the new dye drums and eduction probe. If you are not now using the dry-dye eduction system, our Operations Group will be glad to help you set up the complete installation.

**A STANDARD** 2-inch pipe plug keeps the dye drum tightly closed once the seal has been broken.

## ASSISTANT MANAGER OF OPERATIONS

RUSSELL B. DAVIS has been attached to the Operations Group of the Du Pont Petroleum Chemicals Division since 1947. He currently supervises the work of this group, whose chief concern is to help refiners maintain safe, efficient handling of tetraethyl lead and other additives.

His contributions to safer TEL handling and more efficient plant operations in connection with the use of additives have been many. He played an important part in the development of such Du Pont-designed equipment as the metal-flex unloading hose, the siphon starter and the new, non-clogging dry-dye eduction probe.

After joining the Du Pont Company in 1933, his first assignment was in the Rayon Department. He was later transferred to the Engineering Department. From 1936 to 1947, he held a number of manufacturing positions in the Organic Chemicals Department, mostly connected with TEL manufacture.

Mr. Davis received his Mechanical Engineering degree from Rensselaer Polytechnic Institute. He is a member of the American Petroleum Institute, the National Safety Council and Sigma Xi Fraternity.

## NEW DYE BOOK AVAILABLE

### Gives detailed information on coloring all types of petroleum products

With the public becoming more and more color-conscious every day, refiners and marketers are putting increased emphasis on coloring all types of petroleum products.

Gasolines have been dyed for many years to indicate TEL content—also for brand identification. However, only recently have brilliantly hued greases, lubricating and home heating oils, kerosines and diesel fuels begun to appear. The merchandising advantages of using eye-appealing color for brand identification are no doubt an important reason for this trend.

To help refiners use petroleum dyes as effectively and economically as possible, we have just published a new manual on coloring petroleum products. All the latest methods of addition—including dry-dye eduction—are covered in this 20-page book.

It also contains data on meeting color requirements for military, aviation and leaded motor fuels. And full information on Du Pont Petroleum Dyes—with solubility charts and spectrophotometer curves—is included.

Just address your request for this book to one of our Petroleum Chemicals Division sales offices. Ask for a copy of "Du Pont Petroleum Dyes."

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would make their use prohibitive. Thus, for example, the moderate size of the linear programming example was set by the fact that a high-speed computer was not available. Problems of the size of 100 equations in 300 variables have been machine-computed, as compared to 10 equations in 22 variables for the blending problem.

**Conclusion.** Many people will argue that a great deal of the concept described here is not operations research, but industrial engineering, business research, quality control engineering, or applied statistics. It is true that operations research borrows heavily from all these fields. However, the name, Operations Research, appears to be an excellent one for a much wider field than any of the other disciplines. The term operation includes many activities besides those of business and industry, and research implies a more extensive use of theory and verification of theory by experiment than does earlier terms.

So, its name is warranted and is a fortunate choice. But it is not essential for the work. Most important are the investigative policies, those of science, those of separating what is known from what is not known. Knowledge of this gives business and industry the best possible basis for decisions.

That an approach of this type should be successful could, perhaps, be predicted from the achievements of research in engineering and the physical sciences. That it is successful is being brought out by the problems to which it is being applied, as described in the numerous papers giving OR case histories.


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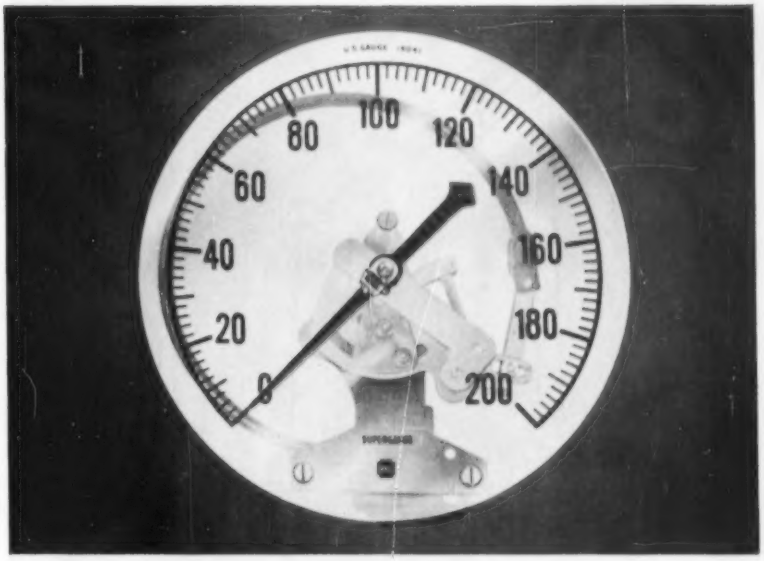


# New Supergauge Movement Extends Gauge Life; Gives Users Many Extra Benefits

In the quest for longer gauge life under severe operating conditions, one of the principal hurdles confronting instrument engineers has been the problem of gear tooth wear. Many efforts have been made to solve this problem including the use of materials other than metal.

U. S. Gauge research indicated nylon rolling on stainless steel provided the best solution if proper control of the nylon were achieved. All past experience showed that expansion of the nylon when subjected to heat and humidity changed pitch diameter causing binding and wear. This destroyed the gear rolling action, thus defeating its main advantage of assuring longer gauge life under severe operating conditions.

Using a new approach to the problem, U. S. Gauge engineers developed the new *ARC-LOC movement.

Molded nylon is bonded to the face of the stainless steel segment to maintain pitch diameter. Gear teeth are then accurately generated on the nylon face to assure perfect rolling action on the stainless steel pinion. The segment gear face is broad and all bushings or pivots are deep to assure strength and ruggedness. The result is longer gauge life under severe operating conditions.

Since nylon is applied to the arc of the sector, any tendency of the nylon to grow or shrink occurs along the periphery instead of along the radius. Thus, accurate pitch diameter is maintained and there is no wear from binding. With this design, the smooth gear rolling action between segment and pinion continues even under adverse conditions of heat and humidity.

The new U. S. Gauge ARC-LOC movement also provides several additional features of interest to the user: For easier adjustment the complete movement can be rotated about the pinion axis, positioned properly and locked from the rear. This provides the advantage of linearity adjustment without removing dial and pointer. The unique locking method also eliminates creep during locking.

The Arc-tang segment allows range adjustment without resetting of the pointer.

These added advantages mean savings in time during calibration . . . an important factor in maintenance reduction.

For complete information on the savings that are made possible by U. S. Gauge's new Supergauges and Solfrunt gauges with the new ARC-LOC movement, write for Publication 1819.

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UNITED STATES GAUGE

Division of American Machine and Metals, Inc.

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*Home of the* SUPERGAUGE




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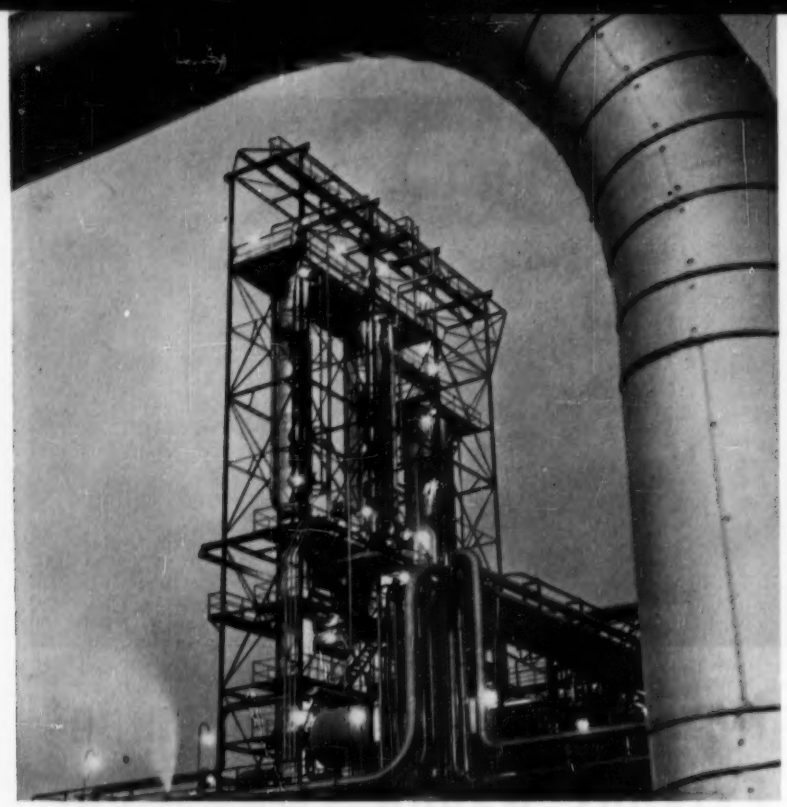


FIGURE 1—Shown above is but one example of rapid reconstruction and expansion in Europe by the Royal Dutch/Shell Companies. This is the gas section of the company's crude distilling unit No. 4 at the Pernis refinery in Holland.

**Postwar Construction**

# From Chaos to Europe's Leading Refiner

**Royal Dutch/Shell's remarkable recovery from the destruction of World War II is a study in brilliant industry operations.**

DURING THE past ten years, the Royal Dutch/Shell Group companies have spearheaded a construction program calling for the erection of processing facilities on an unprecedented scale. Most of the construction work has been carried out during the past five years, since many materials were virtually unobtainable in the years immediately following Word War II.

Result of these years of activity: Royal Dutch/Shell is now the largest crude oil refiner in Europe.

Cessation of hostilities in 1945 confronted Royal Dutch/Shell companies with great technical problems and heavy financial expenditure. New construction during the war was severely restricted to the building of a relatively small number of installations, such as those at Curacao, to insure the adaptation of refinery operations to meet special military requirements.

The return of peace brought about an enormous increase in the demand for oil products. Both the traditional products and many new ones now had to be produced under conditions which, owing to the desperate shortage of construction materials in the early post-war years, were extremely difficult.

**War Damage Was Heavy**—The program of the Shell Companies was further complicated by the complete or partial destruction of several refineries in Europe and Asia, even though in many cases the reconstruction involved paled into insignificance in comparison with the post-war expansion.

The Pernis refinery near Rotterdam, for instance, the capacity of which in 1939 was about 20,000 barrels daily, had been heavily damaged, and its reconstruction was accompanied by an enormous and rapid expansion, with the result that by the end of 1955 its capacity was 220,000 barrels daily. For the manufacture of high octane gasolines and of base materials for chemicals a catalytic cracking unit has been built, while a second one is under construction. Storage capacity for crude oil and finished products was enlarged to 12½ million barrels by tankage under construction.

The latest figures show that the four refineries of the Shell Companies in the United Kingdom processed a total of 180,000 barrels of crude oil daily during 1955 as compared with the capacity of 30,000 barrels a day at one refinery, that at Heysham, when it started up early in 1948.

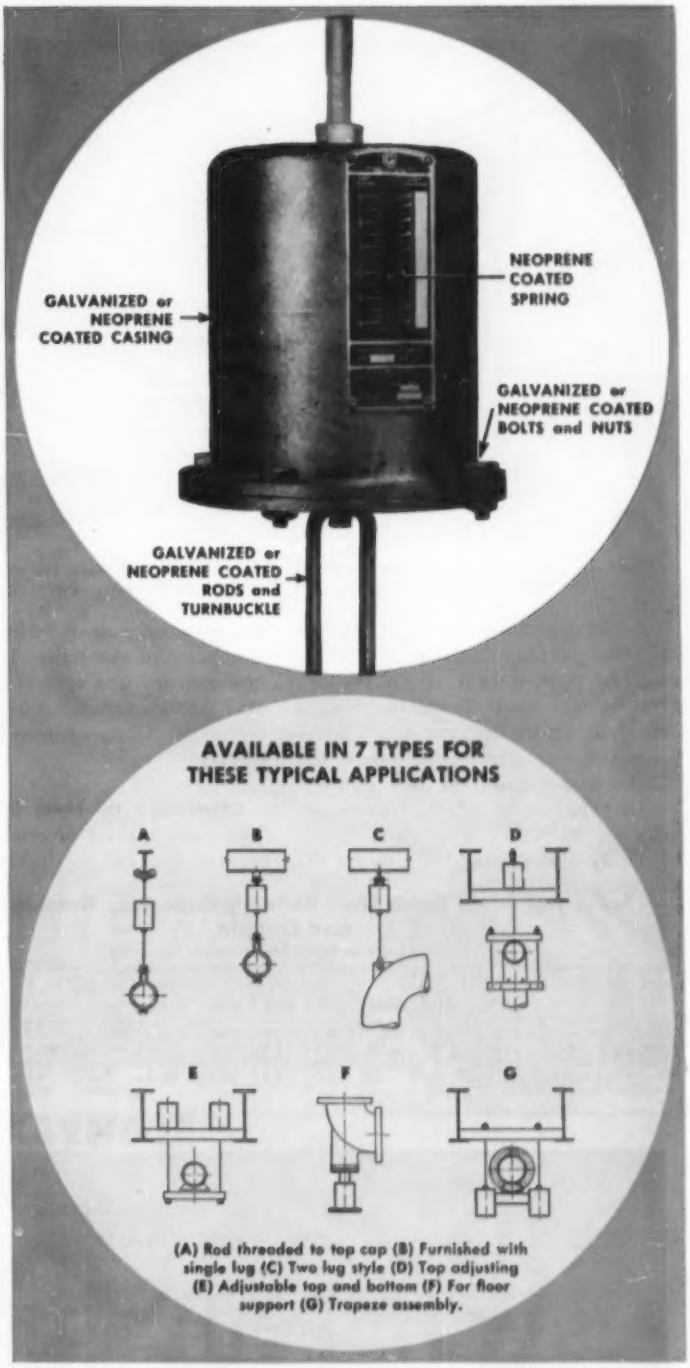
**New Facilities Added**—The general increase in refinery capacity is not due solely to the expansion of old refineries; three new ones have also played an important part. A new refinery of the Compania Shell de Venezuela Ltd. at Cardon went on stream in 1949, its thruput at the end of 1955 being 145,000 barrels daily. A start was made there, not only on the construction of a new catalytic cracking plant, but also on a unit for the manufacture of aviation gasoline.

Furthermore, a fourth and very large crude oil distillation unit is to be built. It will enlarge the capacity of the Cardon refinery in the near future by 80,000 barrels daily.

# NEW

## weather-resistant, corrosion-resistant

# GRINNELL VARIABLE SPRING HANGERS...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GALVANIZED or NEOPRENE COATED BOLTS and NUTS
GALVANIZED or NEOPRENE COATED RODS and TURNBUCKLE
AVAILABLE IN 7 TYPES FOR THESE TYPICAL APPLICATIONS
A
B
C
D
E
F
G
(A) Rod threaded to top cap (B) Furnished with single lug (C) Two lug style (D) Top adjusting (E) Adjustable top and bottom (F) For floor support (G) Trapeze assembly.

### Another Grinnell First!

Grinnell pre-engineered spring hangers are now offered in two new lines to meet the need for spring hangers in installations subject to highly corrosive industrial conditions and to severe weather exposure.

These hangers are the result of extensive experimentation with various coatings for Grinnell's standard pre-engineered spring hangers. In addition to providing flexibility in pipe suspension, they provide versatility of application through their corrosion-resistant characteristics. They are . . .

1. Neoprene coated — for highly corrosive conditions such as those found in chemical plants and refineries. *All* parts of the hanger are neoprene coated to protect the base metal from a wide range of corrosives. The flex life of the spring is unaffected by the neoprene . . . the coating resists cracking or flaking over a wide temperature range.

2. Galvanized — for outdoor installations where weather conditions are severe. All parts of the hanger are galvanized except the spring, which is neoprene coated to avoid alteration of temper, hydrogen embrittlement and decreased flex-life of the spring — usual hazards to springs from the galvanizing process.

**Along with the obvious advantages of such corrosion and weather-resistant characteristics, consider these features . . .**

- Maximum variation in supporting force per ½" of deflection is 10½% of rated capacity — in all sizes.
- Precompression* assures operation of spring within its proper working range, as well as saving valuable erection time. Reduced over-all height saves space.
- 18 sizes available from stock for load ranges from 53 lbs. to 12,000 lbs.
- Available in 3 spring lengths for travel ranges of 1¼, 2½, and 5 inches.
- Installation is simplified by integral load scale and travel indicators.

**Precompression is a patented feature.*

# GRINNELL

**AMERICA'S #1 SUPPLIER OF PIPE HANGERS AND SUPPORTS**

**Grinnell Company, Inc., Providence, Rhode Island • Coast-to-Coast Network of Branch Warehouses and Distributors**

pipe and tube fittings • welding fittings • engineered pipe hangers and supports • Thermolier unit heaters • valves
Grinnell-Saunders diaphragm valves • pipe • prefabricated piping • plumbing and heating specialties • water works supplies
industrial supplies • Grinnell automatic sprinkler fire protection systems • Amco air conditioning systems



For more data on advertised products, use Readers' Service Cards, last page.

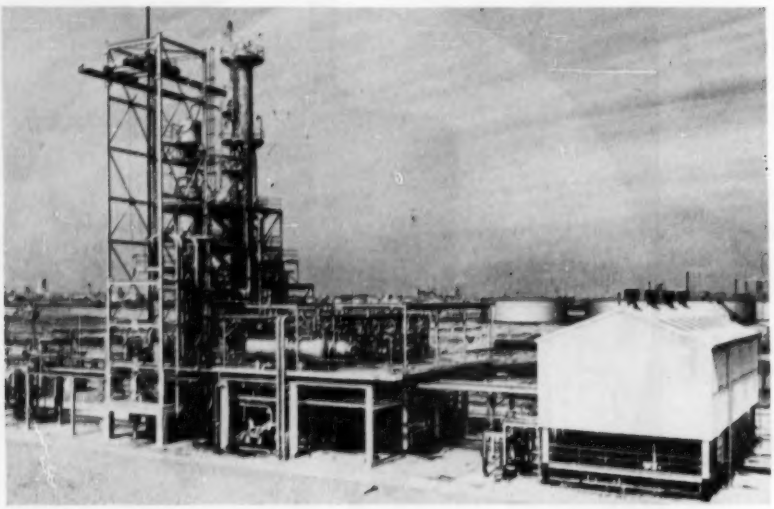


FIGURE 2—The Shell group's hydrodesulphurizer at Stanlow, England—just one of the many new Shell plants that have broken the English skyline since World War II.

In 1955 a new refinery, in which a Group company holds a 50 percent interest, was started up in Bombay for Burmah-Shell Refineries, Ltd. A catalytic reforming unit and a kerosine solvent treating plant are still under construction at this refinery, with capacity of 40,000 barrels per day.

In Australia, in addition to the existing refinery near Sydney of Shell Company of Australia, Limited, a new refinery was opened at Geelong, near Melbourne, early in 1954, with a crude oil intake of some 22,000 barrels daily.

**Challenge of New Demands**—The total amount of crude oil processed in Europe, South America, Asia and Australia rose from 400,000 barrels per day in 1946 to 1,400,000 barrels per day in 1955. But this increase, although in itself quite impressive, does not give the complete picture of what the Royal Dutch/Shell companies had to undertake to continue playing its active role as one of the world's leading oil suppliers. In addition to crude-distilling facilities, secondary processing facilities had to be installed to meet the requirements of a market which had become increasingly quality-conscious.

It therefore became necessary to construct additional catalytic cracking plants and integrated luboil plants consisting of solvent extraction, deasphalting, dewaxing and clayheating plants.

Several "platformers," further contributing to the manufacture of premium grade motor gasoline, have been built during the past few years, while an additional number of such installations are under construction or planned.

However, quality improvement has not been limited to motor gasolines and lubricants. There is a trend, notably in the middle-distillate product range, towards a lower sulfur content, and this has brought about the development of various processes for sulfur removal.

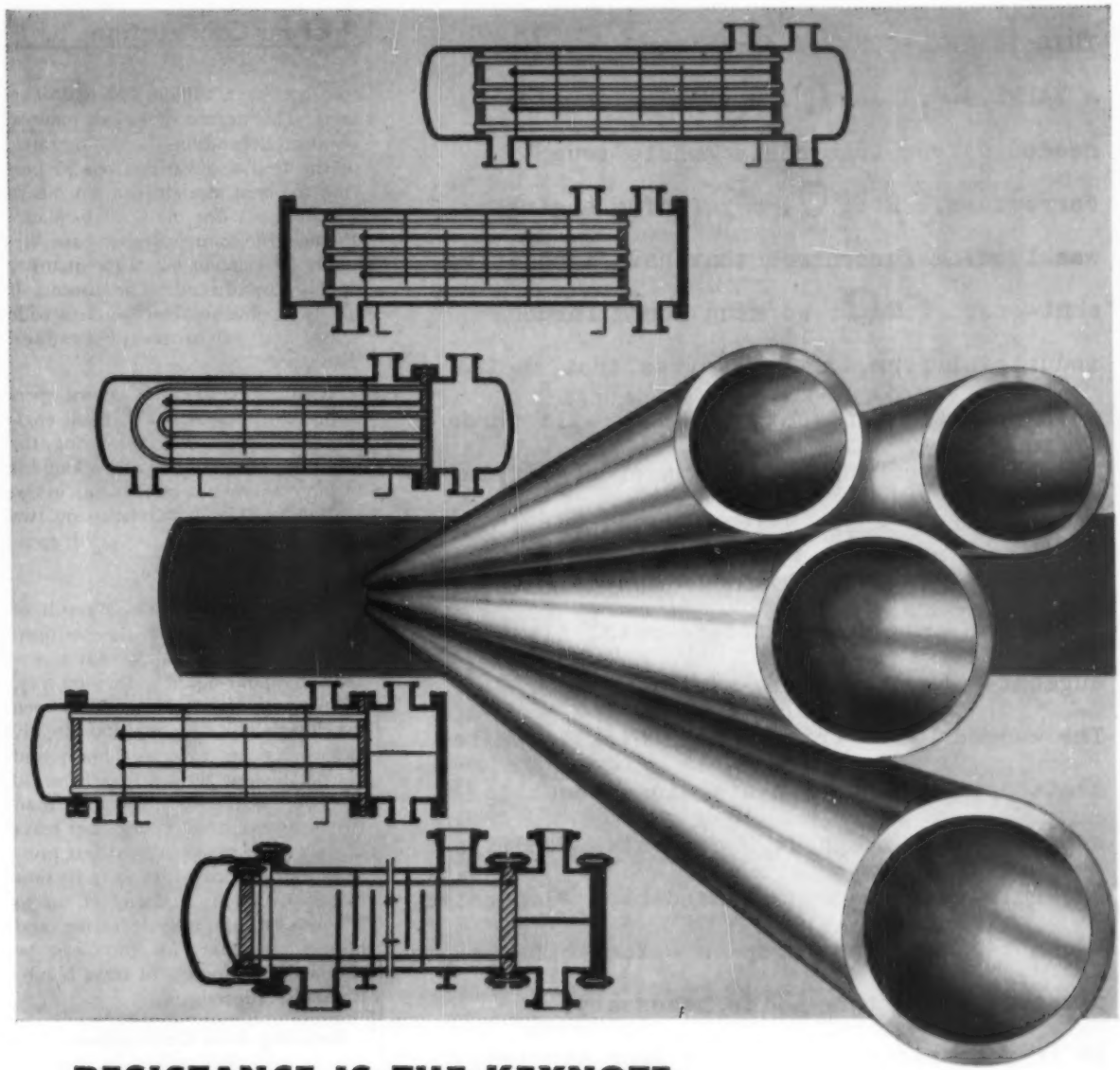
The Royal Dutch/Shell companies made their contribution in this field by the introduction of hydrodesulphurization using the "trickle" technique. This is a mild catalytic hydrogenation process in which all types of sulfur compounds are converted

**Survey of Royal Dutch Shell Refinery Capacities Outside U.S.A. and Canada**

All Figures in Thousands of Barrels Per Day

| | 1946 | 1947 | 1948 | 1949 | 1950 | 1951 | 1952 | 1953 | 1954 | 1955 | 1956 Est. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Crude Oil Distilling | 400.0 | 475.0 | 605.0 | 695.0 | 860.0 | 990.0 | 1105.0 | 1250.0 | 1315.0 | 1405.0 | 1415.0 |
| Thermal Cracking | 140.0 | 145.0 | 145.0 | 170.0 | 175.0 | 180.0 | 180.0 | 180.0 | 180.0 | 200.0 | 200.0 |
| Thermal Reforming | 15.0 | 25.0 | 25.0 | 45.0 | 65.0 | 80.0 | 80.0 | 85.0 | 85.0 | 90.0 | 90.0 |
| Catalytic Cracking | .... | 0 | 5.0 | 5.0 | 5.0 | 30.0 | 55.0 | 70.0 | 70.0 | 100.0 | 150.0 |
| Catalytic Reforming | .... | .... | .... | .... | .... | .... | .... | 10.0 | 10.0 | 10.0 | 40.0 |

FIGURE 3—Royal Dutch/Shell's cracking and distillation sections with Luboil complex at the company's Cardon refinery, Venezuela.



# RESISTANCE IS THE KEYNOTE

Resistance to corrosion and contamination of product is the job of B&W Condenser and Heat Exchanger Tubes in the process industries. In myriad processes where resistance to these factors is a major consideration, selection of the best tube steel analysis for optimum performance is of paramount importance in any application.

B&W offers a wide variety of grades, seamless or welded, to meet virtually every requirement, economically and dependably. In addition to designers' preferences, shop men like B&W Tubing because they know from experience that B&W Tubes are easy to bend, to roll in, and to weld.

B&W Condenser and Heat Exchanger Tubes are included in the comprehensive warehouse stocks of many helpful, well-informed independent B&W tubing distributors. The Babcock & Wilcox Company, Tubular Products Division, Beaver Falls, Pa.

B&W
TUBULAR PRODUCTS DIVISION

TA-6098-GP

Seamless and welded tubular products, seamless welding fittings and forged steel flanges—in carbon, alloy and stainless steels

THIS IS THE STORY of three men and a VALVE. Joe, a chemical engineer, needed valves that could handle tough corrosives. Bill, a refining engineer was looking for valves that gave a positive shut-off. Tom, working for a large industrial firm, needed valves that sealed both upstream and downstream. All three solved their problems by specifying Hamer Visible Wedge Valves. These remarkable valves combine the double sealing action of precision metal-to-metal fit augmented by dependable seal rings.
The wedges are trimmed with nickel, while seats are trimmed with stainless steel to withstand the roughest corrosive conditions.
The full-view wedges are handwheel operated --can't blow out or drop on a toe. The wedges pivot so no lifting is necessary.
So if your plans require long service, sure-seal shut-off valves, by all means specify
HAMER VISIBLE WEDGE VALVES.
P.S. For descriptive literature, write:

Hamer VALVES, INC.
2919 Gardenia Ave., Long Beach 6, California
Representatives Throughout the World.

## Postwar Construction . . .

into hydrogen sulfide and hydrocarbons. The degree of sulfur removal obtained depends on the boiling range of the feed and varies from 95 percent for light straight-run gas oils to 75 percent for flashed distillates. Product yields in all cases are virtually 100 percent minus the quantity of $H_2S$ produced. The process is highly flexible and can handle a wide range of straight-run or cracked distillates.

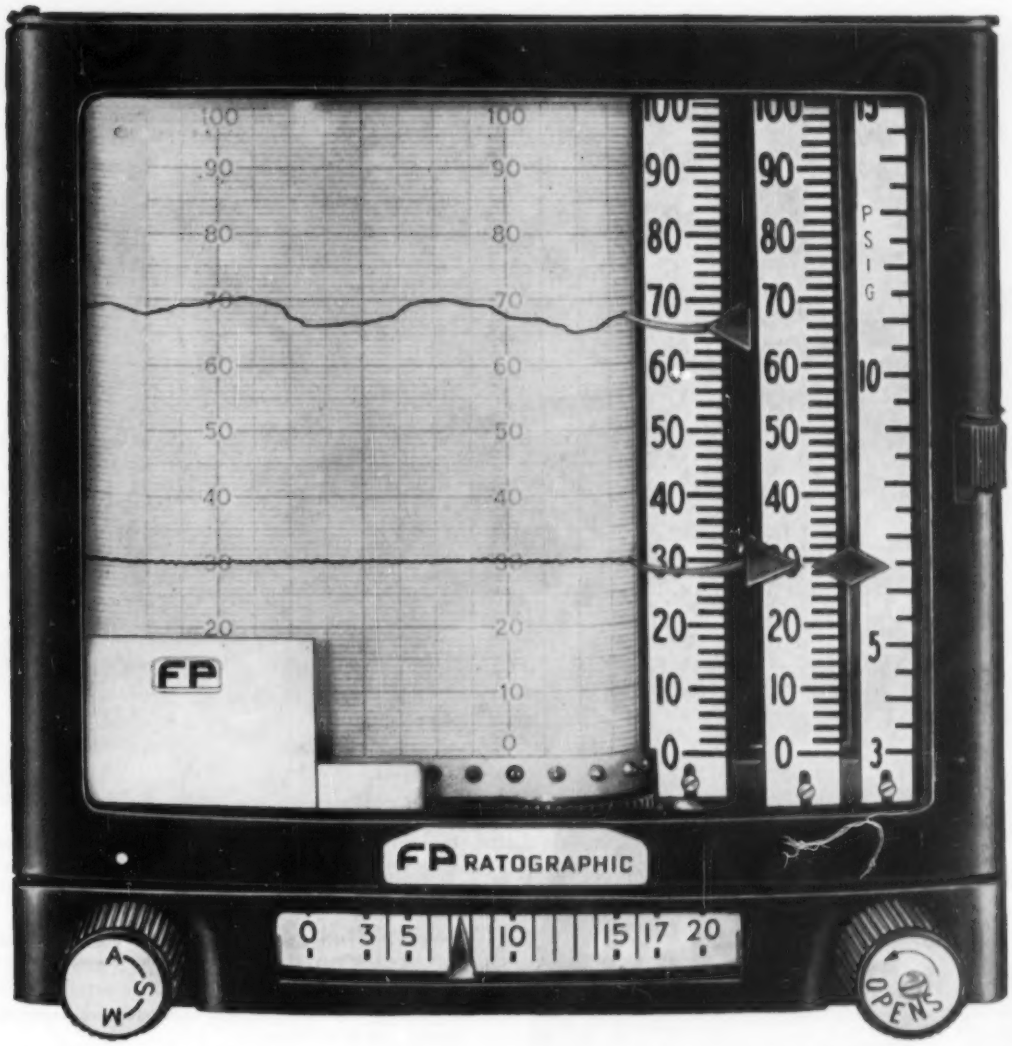
With a view to cutting down operating costs, Royal Dutch/Shell engineers are constantly improving the efficiency of operations. Of a long list of innovations and refinements in operating technique, the following two items are particularly worth mentioning:

**Turbogrid Trays**—As a result of extensive research on the performance of distillation equipment a new type of vapour-liquid contacting tray, known as a turbogrid tray, has been developed. This tray, which is already extensively employed in refinery and chemical plant service, has from 50 to 100 percent greater capacity than the conventional bubble cap trays and as much as 80 percent less pressure drop per tray. Owing to its simple construction, a saving of up to 50 percent on manufacturing and installations costs for trays can be obtained, and fouling of trays is substantially reduced.

**Rotating Disc Contactor**—For solvent extraction systems a new extractor, the rotating disc contactor, has been developed which has many advantages over conventional types of extraction equipment, e.g., greater efficiency, lower construction cost and more flexibility in operation. RDC's have been installed in new furfural extraction units for luboil manufacture and for the chemical industry. Excellent characteristics have been shown in these commercial-scale applications.

Aiming at greater efficiency and more flexibility in operation, the Royal Dutch/Shell Group of companies is continuing to work energetically on new extensions and improvements in processing methods, to meet the steadily growing demand for higher-quality oil products in ever greater quantities. ##


For more data on advertising products, use Readers' Service Cards, last page.




## Fischer & Porter has the answer... it's ***READABILITY***

Look at the actual size illustration above. Notice how horizontal chart travel assures quick, easy readability. Side writing pens mean accurate reading of chart record. The entire instrument may be withdrawn from case, making visible a 14 hour chart section, *without interrupting operation of the recorder or controller in any way*. There are no other instruments like these using full four inch charts.

F&P Ratographic Recorders may be quickly interchanged from the *front* of the panel. Servicing is simple. Automatic seal-off. Consider the continuous chart rewind with handy daily tear-off. Consider the removable pens, fed from an adequate ink supply reservoir. Yes, consider *all* the F&P Ratographic advantages and you'll buy no others.

These instruments mount readily on conventional or graphic panels. Specify any of many options and F&P has the answer. A single F&P Ratographic Recorder in use will convince you of their versatility, high accuracy and dependability. That's a firm assurance. Write today for complete information or specific quotations. Fischer & Porter Co., 1026 County Line Road, Hatboro, Penna.

***Illustrated Literature on Request***

*Catalog 55-20 is a complete, detailed report on the multiple applications, the many options available in F&P Ratographic instruments. Write for it today. No obligation, of course.*

**FP FISCHER & PORTER CO.** Hatboro, Pa.

COMPLETE PROCESS INSTRUMENTATION



For more data on advertising products, use Readers' Service Cards, last page.

# Brown Fintube

The above photo shows a large Houston Petro-Chemical (Synthetic Ammonia) Plant with 9 compressor stations . . . a total of 54 coolers or 306 high pressure heat exchanger sections. Pressures from 72 psi to 5300 psi.

Brown high pressure heat exchanger sections are now performing, with high efficiency, in almost all the Petro-Chemical plants that have been built in the last five years.

BFT high pressure sectional heat exchangers are available for pressures up to 22,000 psi.

# *High Pressure*

## HEAT EXCHANGER SECTIONS

HEAT EXCHANGE SURFACE
BROWN FINTUBE
HEAT TRANSFER PRODUCTS

## BROWN FINTUBE COMPANY

*Elyria, Ohio*

***Engineering and Sales Representatives in the Principal Cities***

# What's Happening . . .

## . . . in the Industry

## Forecasts Hike In Oil Demand

Reflecting continued confidence in the general business outlook, E. T. Knight, The Atlantic Refining Co., Philadelphia, speaking at the session on petroleum statistics at the American Petroleum Institute's 36th Annual Meeting estimated 1957 daily requirements of petroleum products would run about 9,598,000 barrels.

Domestic demand, he said, is expected to run about 9,265,000 barrels a day, an increase over 1956 of 366,000 or 4.1 percent.

Exports of crude oil and products are expected to average about the same as 1956, around 333,000 barrels a day. This forecast, Knight emphasized, could be significantly changed by developments in the Suez Canal dispute.

He said in preparing the domestic forecast the committee recognized the following factors which will affect favorably the consumption of petroleum products: Increased leisure time of passenger-car owners; the growth in the number of two-car families as the switch to suburban living continues; and improvement in highways between distant points, notably the federal highway program which is expected to result in a demand for asphalt 11.7 percent greater than 1956.

Also, as a result of these considerations, gasoline consumption should jump to 3,967,000 barrels daily, a 4.3 percent increase amounting to 163,000 barrels.

Knight noted that the only petroleum product which will be a drop in demand is kerosine, which should average 325,000 barrels per day, a decline of 1.7 percent.

The biggest increase is forecast for liquefied petroleum gas. This product, it is estimated, will run 8.7 percent over 1956, or 482,000 barrels a day.

A modest increase in the use of distillate heating oils is predicted; 3.1 percent on a daily demand estimate of 1,075,000 barrels with a five percent increase in the number of heating units.

In the light of this demand picture and the export-import situation, Knight said domestic crude oil production should average 7,309,000 barrels daily, an increase of 2.6 percent.

Knight also took a five-year look ahead with the estimate that in 1962 domestic demand for all petroleum products will run about 11,110,000 barrels a day, a 20 percent increase over the 1957 forecast. He added, however, that this long-range forecast may be on the conservative side.

### Plastic Cars, Buildings

A new bombardment process that will lead to new plastics tough enough for automobile bodies, aircraft and structural members for buildings. That is the prediction of Dr. Harold Gershinowitz, president of Shell Development Co., who said

### Humble Buries "Hot" Waste

The first burial of radioactive waste at Humble Oil & Refining Co.'s Baytown refinery was recorded recently. Contaminated catalyst used in a research problem at the refinery research center was disposed of according to specifications set up by the Atomic Energy Commission. AEC requires that radioactive material be buried four feet deep, but extra safety precautions were taken.

The catalyst was placed in a metal barrel coated with asphalt mastic. An eight-foot-deep hole was dug and its bottom covered with gravel. The barrel was lowered into a section of concrete culvert pipe in the hole, and a piece of steel boiler plate was laid on top of the pipe before the hole was backfilled.

Warning signs and a barbed wire fence have been placed around the area. In two years, the waste will be dug up and checked for radioactivity. If none exists, it will be disposed of in an ordinary manner.

**New BP Motor Fuel Test Lab.—**

**An observer operating the vehicle dynamometer control panel in The British Petroleum Co.'s new motor fuels engine test laboratory at Sunbury-on-Thames, near London. This control panel permits full control and observation of conditions of the car on test in the vehicle dynamometer and means of inter-communication between the observer and the driver of the car. Road speeds up to 120 m.p.h. can be simulated.**

## What's Happening . . .

the new products will come from treatment of ordinary plastics with high-energy beams of electrons and other atomic particles accelerated to nearly the speed of light and then fired into the material being processed.

"Bombardment will do for plastics what forging did for iron and vulcanizing did for rubber. It changes the nature of the ordinary material, gives it extraordinary new properties and opens the way for new products and new industries, he said.

Shell Development Co. has a new 3-million volt electron accelerator, which Dr. Gershinowitz called "the most powerful radiation source in industry." It is being used in research designed to develop new plastics and to study the effects of radiation on other oil products, especially fuels and lubricants to be used with atomic power plants.

## First Venezuelan Degree

Venezuela has awarded its first degree in Petroleum Engineering to Guillermo Jose Salas who recently finished his studies at the University of Zulia (Maracaibo). All the young Venezuelan's schooling has been taken in his native country with the exception of some work at the University of Tulsa, on a Shell scholarship.


"Alamask"

**offers a complete and diversified line of reodorants for petroleum and allied products**

No longer need the products of the petroleum industry inflict upon their users the obnoxious odors resulting from the mercaptans and sulfides in their processing.

Years of development work and product-testing have culminated in a complete line of Alamask® reodorants that can successfully mask the objectionable odors of many petroleum products. Check this table to see which Alamask reodorants will solve your malodor problems:

| "ALAMASK" | GASOLINE FRACTIONS | ASPHALTIC COMPOUNDS | KEROSENE BLENDS | COAL SPRAY OILS | SPACE HEATERS | CUTTING OILS | CLUTCH OILS | DIESEL FUELS | JET FUELS | MINERAL SPIRITS | WAXES | NAPHTHA | BURNER OILS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AAM | | | | | | | | X | | | | | |
| AO | | | | | | X | X | | | | | | |
| AR | | X | | | | | | | | X | | | |
| BGM | | X | | | | | | | | | | | |
| BN | | | | | | X | X | | | | | | X |
| BUL | | | | X | X | | | X | | | X | | X |
| CC | | | X | | | | | | | X | | | |
| CE | | | X | | | | | | | X | | | |
| CX | | | | | | | | | | | X | | |
| MS | | | X | | | | | | | X | X | X | X |
| 0.19 | X | | | | X | X | X | | X | | | | X |
| 0.20 | X | | | | X | X | X | | X | | | | X |
| TO | | | | | | | | | X | | | | |

Rhodia's chemists and engineers, experienced in odor abatement and waste disposal, will provide technical assistance to you in your efforts to correct malodors.

For complete information on these new, highly-effective reodorants, write today to Rhodia, Inc., Industrial Reodorants ("Alamask") Division, 60 East 56th Street, New York 22, N. Y.

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Philadelphia • Cincinnati • Chicago • Los Angeles • Canada: Naugatuck, Montreal • Cuba: Luis Felipe, Havana • Mexico: Comercial Reka, Mexico City


## "Magic Barrel" Gets Mate

A running mate for its familiar "Magic Barrel" for promoting better public understanding of the oil industry has been developed by E. I. du Pont de Nemours and Co., Inc. Using illustrations largely from petrochemical products, "A 'Brief' Case for Business" explains the roll of large and small business in the American economy. It brings out that size is related to function, and shows how large companies build opportunities for small companies, while at the same time being dependent on the essential operations which small firms are best qualified to perform.

H. C. Thompson, assistant sales promotion manager of Du Pont's chemical division developed the presentation which is to be made available through the national Oil Industry Information Committee.

## SOHIO Eyes Tar Sands

The Standard Oil Co. (Ohio) has embarked on a five-year program to investigate the feasibility of recovering billions of barrels of petroleum from Asphalt Ridge, Utah. If tests disclose that recovery can be done economically, Sohio will build an extraction and "vis-breaking" plant at Vernal, Utah.

## Oil Industry Ups Budget

The U. S. oil industry is spending more than $5 billion this year to expand and improve its facilities to meet increased demands for petroleum products Dr. Robert E. Wilson, Chairman of the boards of Standard Oil Co., (Indiana), and American Oil Co., has declared.

He said that the highly competitive petroleum industry has spent $38 billion for domestic expansion alone since World War II, mostly out of earnings, for more and better petroleum products which still are at bargain prices.

He pointed out that two gallons of modern high-quality gasoline will do the work of more than three gallons of 1925 gasoline, but the price per gallon, excluding taxes, is only slightly higher than in 1925. In horsepower produced, it's actually much cheaper.

In citing other tremendous costs confronting the industry, Dr. Wilson said a well-rounded refinery now costs about $1,000 per barrel of daily capacity. More than $175 million this year will be spent in all branches of the industry for research and development work.

## Opportunities In Oil

The oil industry is the "land of opportunity" for the university graduate of today almost without regard to the department in which he earns his degree. This is shown in graphic fashion in an impressive new recruitment brochure "Careers in Oil and Petrochemicals" just issued by The Standard Oil Co. (Ohio) as part of the company's effort to find the right man for the job in each portion of this fully integrated oil company.

"Careers in Oil and Petrochemicals" pinpoints spots in the company where specific areas of education fit the university graduate for immediate employment and opportunity for continuing educational and intellectual growth through the years ahead.

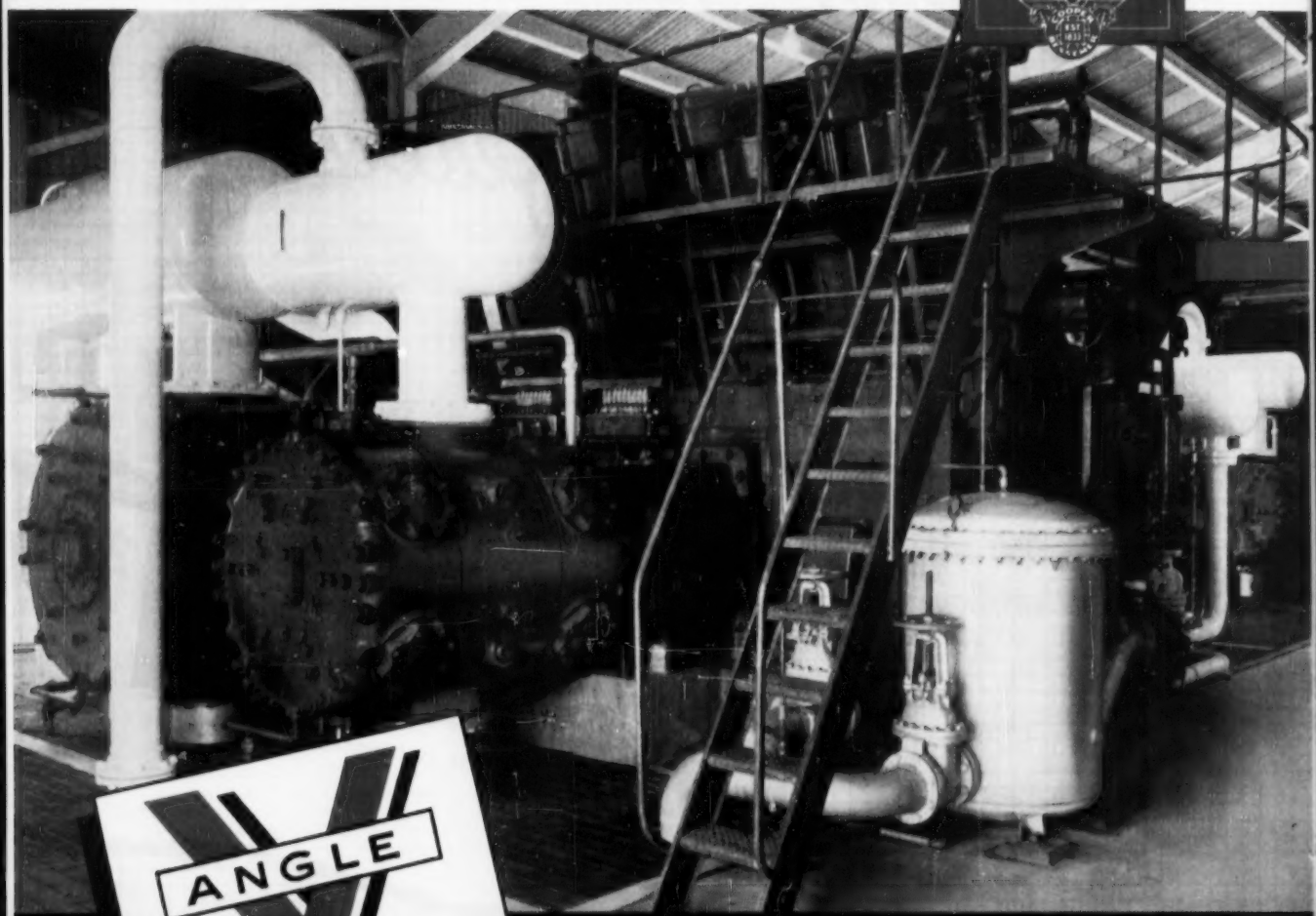
In alphabetical order, this brochure tells exactly how specific subjects fit into the daily operations in the various depart-

*In a water conditioning service... results make the difference!*

*W. H. & L. D. BETZ, Philadelphia, Pa.*

# Full-load operation . . . all the time! with Cooper-Bessemers in high-pressure ammonia service

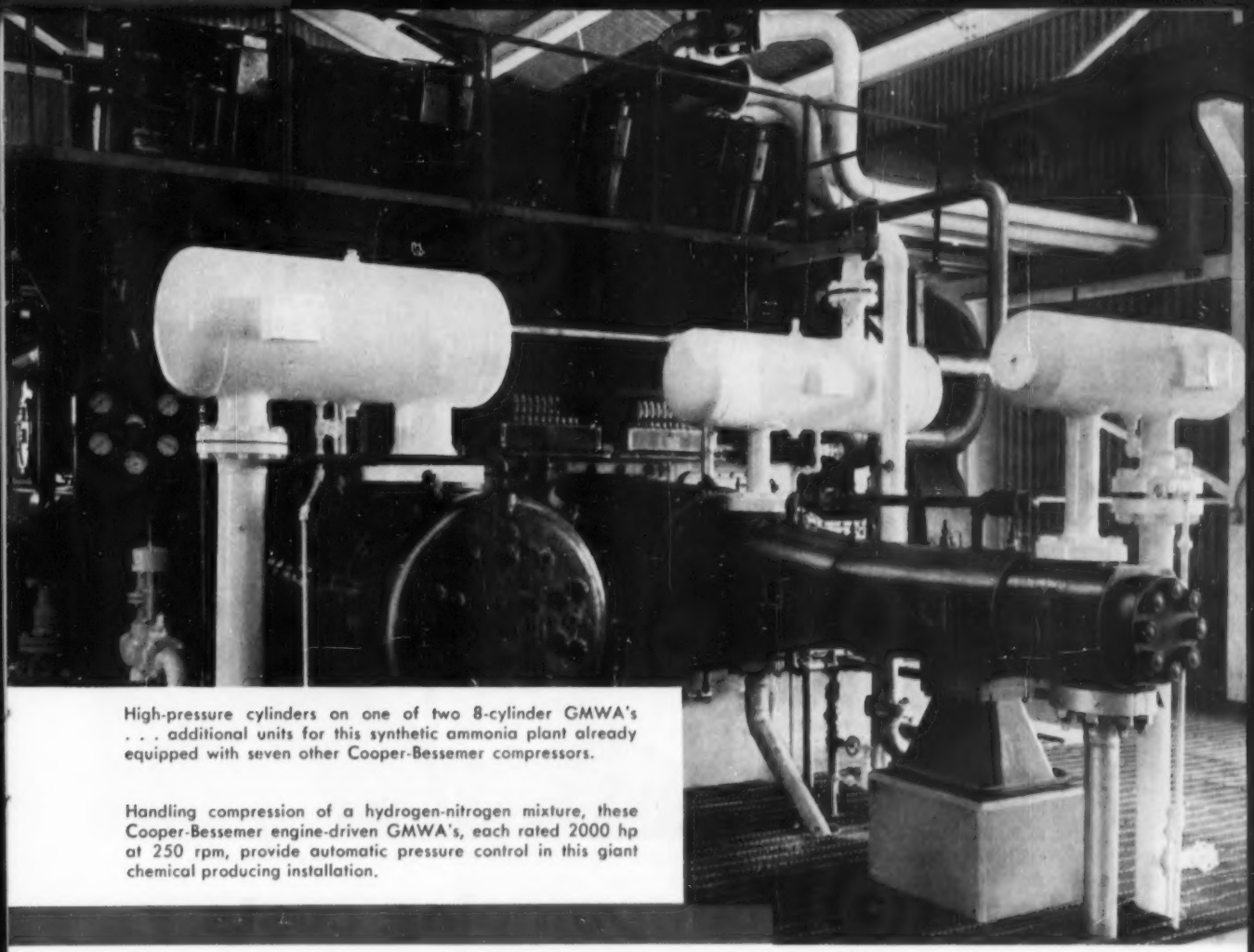
*Another Example of Efficient Power at Lower Cost*



ANGLE

# Compressors

New York City Washington, D. C. New Orleans Los Angeles and San Francisco
Houston, Dallas, Greggton, Pampa and Odessa, Texas Seattle Tulsa Shreveport St. Louis Chicago



High-pressure cylinders on one of two 8-cylinder GMWA's . . . additional units for this synthetic ammonia plant already equipped with seven other Cooper-Bessemer compressors.

Handling compression of a hydrogen-nitrogen mixture, these Cooper-Bessemer engine-driven GMWA's, each rated 2000 hp at 250 rpm, provide automatic pressure control in this giant chemical producing installation.

• When it comes to compressor horsepower, this Texas synthetic ammonia plant has an important advantage in common with scores of other plants throughout this country and abroad . . . they all benefit from the low maintenance, high operating efficiency of Cooper-Bessemer compressors.

The plant shown here, for example, recently added two 2000 hp Cooper-Bessemer GMWA's to meet increased work demands. This one plant now boasts more than 10,000 Cooper-Bessemer horsepower to effectively handle recirculation and the processing of a hydrogen-nitrogen mixture, through five stages, from 2.5 to 5300 psig.

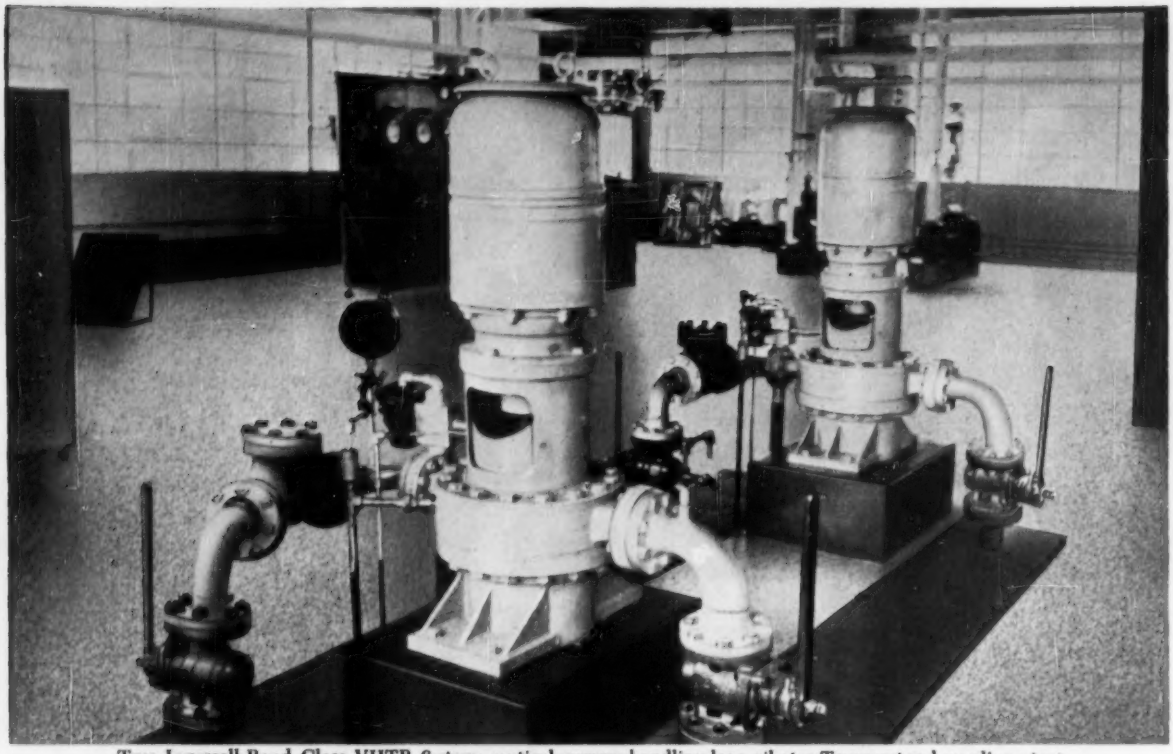
Since Cooper-Bessemers are especially designed to easily handle the most severe work demands, full-time at full-load operation presents no handicap to the smooth service delivered by these work-wise units.

Whether your requirements include heavy-duty compressors for chemical, petrochemical or virtually any other type service, you'll profit by contacting the nearest Cooper-Bessemer office. Let one of our experienced sales-engineers tell you about the latest developments now being offered by one of America's oldest engine and compressor builders . . . Cooper-Bessemer.

*by* **Cooper-Bessemer**

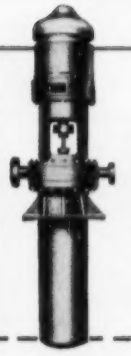
MOUNT VERNON, OHIO AND GROVE CITY, PENNA.
Cooper-Bessemer of Canada, Ltd.
11304, 119th St., Edmonton and 615 Second St., S.W., Calgary, Alberta, Canada

# VERTICAL PUMPS



Two Ingersoll-Rand Class VHTB 6-stage vertical pumps handling lean oil at a Texas natural gasoline plant.

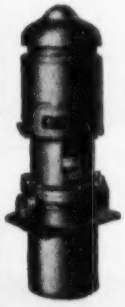
## to lower your pumping costs



**CLASS VHTB**
**Pressures: to 1500 psi**
**Capacities: 25 to 325 gpm**
**Temperatures: to 750°F.**

Vertical, multi-stage diffusor-type unit. Single-suction impellers mounted back-to-back for axial hydraulic balance. Stuffing box under suction pressure.

For low capacities at high heads on process, boiler feed, hydraulic and similar applications.



**CLASS VP**
**Pressures: to 750 psi**
**Capacities: 10 to 350 gpm**
**Temperatures: to 750°F.**

Vertical, multi-stage, diffusor-type construction. Single-suction impellers with throttling sleeve balancing device to reduce axial thrust and provide suction pressure at stuffing box. Entire pumping element removable without disturbing suction and discharge piping.

For low capacities at medium high heads on applications such as process, boiler feed, and heater drain work.

Designed specifically for low-capacity high-head applications, these Ingersoll-Rand vertical process pumps are engineered with a background of process pump experience. They are manufactured in the most modern of pump plants to deliver years of efficient service with a minimum of down time and maintenance expense.

Features include: "Double-Case" construction with segmented diffusor-type inner casing for complete radial hydraulic balance and minimum bearing wear... Positive aligning feature for perfect positioning of inner casing segments... Rotor assembled without prestressing shaft to eliminate all possibility of shaft distortion. Available in bronze fitted, all iron, carbon steel, and stainless fitted materials to cover a wide range of process services.

Ask the Ingersoll-Rand engineer to show you these and other features which make Ingersoll-Rand pumps your best bet for low cost year-in, year-out service.

**Ingersoll-Rand**

10-376 **11 BROADWAY, NEW YORK 4, N.Y.**

**COMPRESSORS • GAS & DIESEL ENGINES • AIR & ELECTRIC TOOLS • CONDENSERS • PUMPS • ROCK DRILLS • VACUUM EQUIPMENT**

ments. Each educational field is illustrated with photographs of men at work throughout Sohio departmental operations.

Students on 110 American campuses this year will have an opportunity for interviews with recruiting representatives of Ohio Standard. Through placement offices and professors at 100 other American universities, students will be able to examine this recruitment booklet and to further explore employment possibilities with the company.

## Maps Brazilian Future

Two officials of Petro Brasilerio, Rio de Janeiro have predicted a bright future for the petroleum industry in Brazil. C. Campbell Williams and Antonio Saebra Moggi said this future would include:

Increased exploration and crude production.

Expansion of refinery capacity by 1960 to 333,000 barrels a day which will be 100 percent of internal needs.

Expansion of their tanker fleet from 200,000 to 400,000 tons by 1960.

Creation of a Brazilian Petroleum Institute.

Increase in capital assets to 35 billion cruzeiro.

They reported that: "In less than 2½ years Petrobras has tripled the crude production in Bahia, found oil in the Amazon basin, greatly increased the exploration crews, successfully operated and expanded her refineries, finished a fertilizer plant, projected several new refineries, and operated a competent training center."

Since 1950 Brazil has constructed five refineries to refine 55 percent of the nation's needed petroleum products. Now being constructed are a 90,000 b/d catalytic cracking plant and a 3000-barrel-a-day lube oil plant. Nearby to these plants the usual petrochemical plants are being built or planned.

Although Petrobras, which is 51 percent government and 49 percent public owned, has sole right for exploration, production and refining of petroleum, the two authors hope that the law would be relaxed in favor of private companies.

Under the present law privately owned refineries cannot expand their existing units, but perhaps a modification of the law may soon allow well-run refineries to expand, they said.

There are private refineries at Manaus, Rio de Janeiro, Sao Paulo and at Rio Grande.

## Monsanto to Keep Pace

The Research and Engineering division of Monsanto Chemical Co., will establish a special laboratory to do research and development work on problems relating to national defense and national welfare which complement Monsanto's long range projects.

The new group, to be known as the special projects department, will occupy the company's laboratory facilities at Everett, Mass. Research personnel of the Inorganic Chemicals division, who now use the Everett facilities, will be transferred to a new laboratory at Creve Coeur, Mo.

## Unit Still Operating

The first Texaco oil gasification unit established by Establissements Kuhlmann at Paimboeuf, France, continues to operate satisfactorily producing synthesis gas under pressure from sulfur-bearing fuel oil. This is the word that comes to Texaco Development Corporation, New York. Kuhlmann reports extremely stable operation while producing synthesis gas of uniform composition with lowest methane content.

This, the first oil gasification unit operating on the Texaco synthesis gas generation process was started late in the summer.

## Leonard to Use Color

Leonard Refineries, Inc., is another company that has decided to give the technicolor treatment to its refineries and other company installations. The company will use a red, white, and blue color scheme. Reasons for the variegated upsurge: easier identification for maintenance and operation, improved working conditions.

# What's Happening. . .

## Tons of Butyl Rubber

A new pilot plant that turns out a ton or more of butyl rubber a day for experimental purposes has gone into service at the Esso Research Laboratories.

Butyl rubber, which was invented by Esso Research & Engineering Co., is made synthetically from refinery gases—isobutylene and isoprene—at a temperature of minus 140°.

The new plant is part of experimental equipment which includes a smaller, 200-pound-a-day butyl pilot plant, a low-temperature laboratory for fundamental


There Are Effective

Corrosion Inhibitors for

COOLING SYSTEMS...

WRIGHT PENECHROMES, *for Example*

**Versatile:** *Effective throughout a wide pH range and inhibitor concentration.*

**Non-fouling:** *Maintain high heat transfer rates at product side temperatures up to 600°F. and higher.*

**Labor saving:** *May be proportioned directly from the drum. No mixing — no chemical vats.*

**Why?** *Because the Penechromes have been using the combined effect of zinc chromate and penetrants for many years.*

When you contact your Wright Field Engineer you will be pleasantly surprised at the modest *cost to use* these outstanding inhibitors. . . . One of them can solve your *exact* problem. Ask your Wright Engineer to survey your water using system and submit our recommendations for a comprehensive water conditioning program without obligation.

Wright CHEMICALS

WRIGHT CHEMICAL CORPORATION
GENERAL OFFICES AND LABORATORY
615 WEST LAKE STREET, CHICAGO 6, ILLINOIS
Offices in Principal Cities
(Havana, Cuba: Domenech & Co., S. A., 405 Obrapia)

- Softeners, Filters and other external Treating Equipment
- Nelson Chemical Proportioning Pumps




For more data on advertising products, use Readers' Service Cards, last page.

## What's Happening . . .

studies of butyl polymers and complete equipment for making finished rubber from the raw product produced by the two pilot plants.

The ton-a-day pilot plant is being used to test new ideas for improving butyl rubber, to try out entirely new types of rubbers and plastics and to produce relatively large quantities of new butyl compounds for field tests.

Test samples shipped out of the Esso Research Laboratories normally are in the form of slabs a foot square and about an inch thick. Also, samples may be diced into tiny pellets.

## Place of Engineers In U. S.

The vital place of the engineers, nationally in defense, internationally on the technological "cold front," and what he should be paid in our expanding economy, are three topics in the 1957 Engineers Joint Council General Assembly, Jan. 17 and 18 at the New York Statler Hotel.

The two-day annual meeting will hear Major General J. B. Madaris and Dr. Werner von Braun of the United States Army Ballistic Missile Agency as well as a senior representative of the U. S. Civil Service Commission and an authority on the highway development program.

"The Engineer and the American Economy" is the title of the address by Professor John Bell Rae of Case Institute of Technology, Cleveland, Ohio. This will be followed by an panel analysis of the salary structure of engineers. Latest available data on professional income of engineers and the principal methods of salary administration will be presented.

The relations of the engineer to the international scene and his vital role in the maintenance of the balance of technological power in the world will be presented Friday. In conclusion, the Assembly will hear W. A. B. Illiff, Vice President, International Bank for Reconstruction and Development, talk on "Overseas Development, Engineers, and the World Bank."

## 500,000 b/d to Europe

An emergency plan which authorizes 15 U. S. oil companies to act together through the Middle East Emergency Committee, has gone into effect to bolster Europe's dwindling oil supply. The immediate goal is to provide Europe with at least 500,000 b/d of oil from the Western Hemisphere within one month; this is about 200,000 b/d more than the continent has been getting from the Gulf Coast since the Suez Canal closure.

Under the committees plan of action, each major move must be cleared with the Interior Department and the Justice Department, which must watch for antitrust entanglements.

Once the emergency plan has reached its maximum efficiency, however, Western Europe is still expected to suffer a deficit of from 20-25 percent of normal oil supplies. Government officials see no "substantial" cost to the U. S. taxpayer in carrying out this program, and no European country has yet requested financial aid. U. S. is still confident that European financial resources are sufficient without dollar aid for, "some little time."

In the meantime, refiners in United Kingdom have been forced to cut their refinery runs by as much as 25 percent. This is in spite of the fact that the first tankers bringing crude from the Western Hemisphere have commenced arriving.

British Petroleum has reduced runs 25 percent, and other companies including Shell, Esso Petroleum, and Mobil Oil have also cut runs, but the extent of their cuts was not known.

Trade sources contend that generally speaking, these reductions have been made to stretch stocks, and thereby prevent sharper cuts later.

## No Supply Switch Planned

Two officers from Armed Forces Petroleum Purchasing Agency have returned from Europe after studying the capabilities of European refiners to maintain supply contracts with U. S. armed forces in light of the recent Middle East crisis.

Pending a contrary report by the Officers, however, ASPPA will hold to its present opinion that all contracts with the European refiners will be met adequately and on time. ASPPA has not and does not forsee any need of switching contracts to U. S. suppliers which were originally scheduled for European suppliers. Current contracts have not yet expired, and the next offerings of European bidders are not scheduled until early next year.

## NLRB Certifies Votes

American Oil Co., employes at the Warwick, Va., plant have voted for representation by Independent Oil Workers of


**CHEMICAL & MECHANICAL ENGINEERS**
***are offered opportunity to advance professionally in diversified growth company***

Air Products offers you the opportunity to advance professionally and financially in the field of low temperature processing. The company is the leader in the engineering, design, manufacture, and construction of oxygen plants and systems for the separation of gases such as Oxygen, Nitrogen, Carbon Monoxide, Hydrogen, and other low boiling building blocks of the chemical industry. We must expand the entire organization to meet the increasing demands of the steel, metallurgical, and chemical industries.

The following opportunities are available at Air Products:

- PROCESS DESIGN: To apply thermo-dynamics, fluid flow, heat and mass transfer, distillation, absorption and absorption to the commercial solution of complex gas separation problems.
- ESTIMATING AND ECONOMIC EVALUATION: To study and evaluate the economics of proposed systems and to estimate the cost of complete plants.
- PROJECT ENGINEERING: To coordinate the engineering, design, and construction of complete plants.
- MECHANICAL ENGINEERING: To design turbines, pumps, engines and special machinery to operate at extremely low temperatures. To coordinate the manufacture, procurement, installation and operation of large compressors, drivers and other machinery for the processing of gases and liquids.
- DESIGN ENGINEERING: Process equipment, pressure vessels, piping, structural, plant layout, electrical, instrumentation.
- CONSTRUCTION ENGINEERS: Supervision, start up, and operation.
- RESEARCH AND DEVELOPMENT: To explore new horizons in processing and equipment design. Analytical, experimental, design, pilot plants.
- SALES ENGINEERING: To negotiate the sale of complete low temperature systems for chemical, petroleum, metallurgical, industrial and government requirements.

Openings exist for all levels of experience. Training and rotation are provided. High salaries are combined with a profit sharing and bonus program. Professional development is encouraged—growth is continually creating new managerial positions.

This well diversified company offers an unusual challenge for engineers who seek a professional career in the atmosphere of a dynamic, growing company.

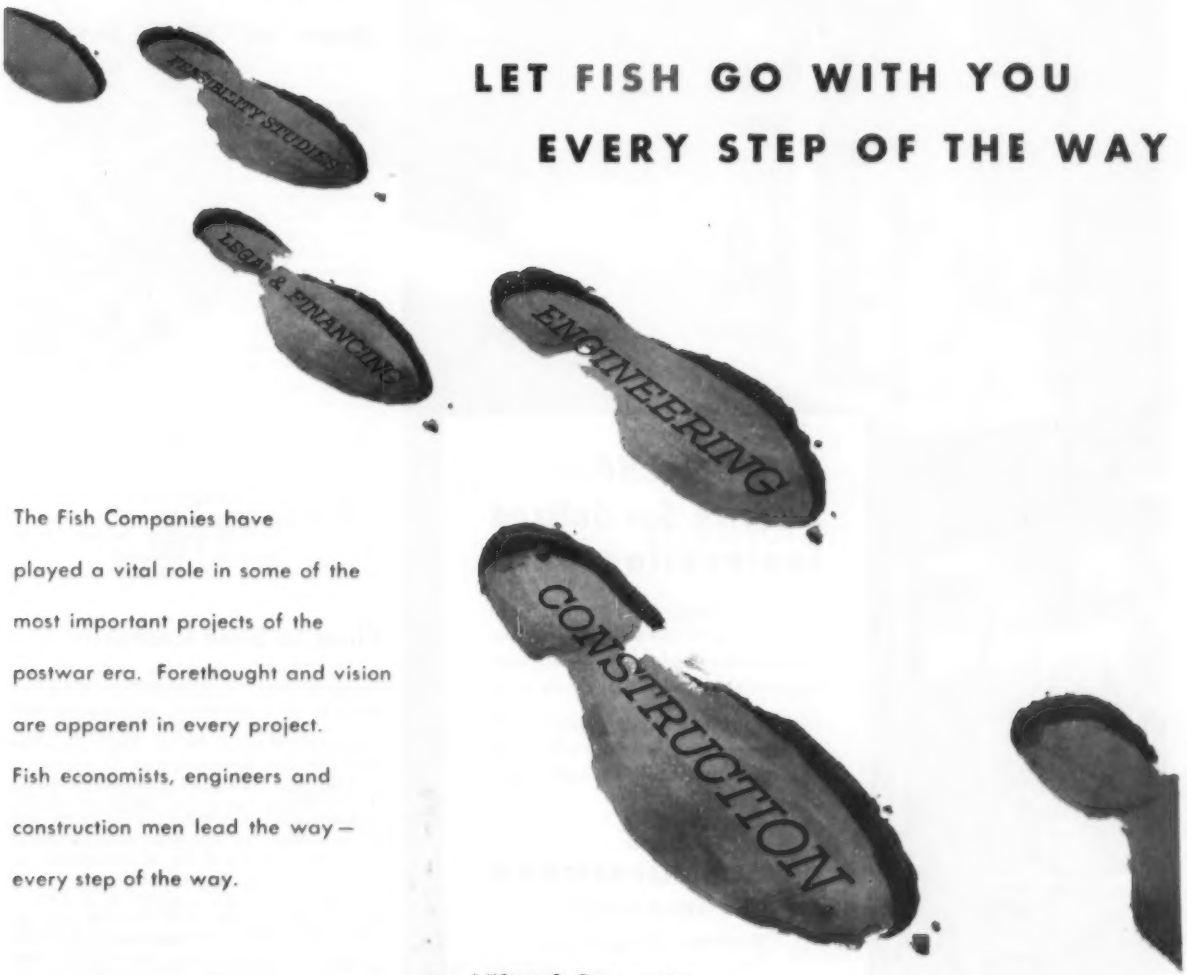
Write in confidence to learn more about our Company.
B. H. VanDyke, Air Products, Inc., P.O. Box 538, Allentown, Pa.

*Air Products*
. . . INCORPORATED
**P.O. Box 538 Allentown, Penna., U.S.A.**

# fish

## ENGINEERING CORPORATION

HOUSTON, TEXAS




## LET FISH GO WITH YOU EVERY STEP OF THE WAY

The Fish Companies have played a vital role in some of the most important projects of the postwar era. Forethought and vision are apparent in every project. Fish economists, engineers and construction men lead the way—every step of the way.

*Affiliated Companies*

**FISH SERVICE CORPORATION**

**FISH NORTHWEST CONSTRUCTORS, INC.**




For more data on advertising products, use Readers' Service Cards, last page.

## What's Happening . . .

Virginia, National Labor Relations Board announced. NLRB has also certified rejection of Oil, Chemical, and Atomic Workers union by vote of employes at Ingram Oil and Refining at Meraux, La.

Meanwhile, an effort to unite independent oil unions into a federation is making substantial progress its leaders say. United Petroleum & Chemical Workers Union was started about a year ago with the intention of giving independent unions more strength without losing their individuality. In general, the coalition plans to form initial wage and benefit programs, but will leave actual negotiations and decisions at the local level.

One reason for the founding of the federation was to prevent the independents from being "swallowed up" by Jack Knight's OCAW.

## Disagree On Intervention

Guaranty Trust Co., and American Chemical Society have appealed a decision by New York Supreme Court which would allow independent oil refiners to intervene in the proposed sale of Universal Oil Products Co., stocks. (PETROLEUM REFINER, Oct., p. 254.)

Independent Refiners Association of America and others have asked to intervene in the case, expressing fears that sale of UOP stocks would deny them access to Universal's patents, licenses, and processes which are presently available to all refiners regardless of size.

***REVAMPS***
**Require Specialized Engineering Skill**

Our wide experience in this field combined with the flexibility of our organization assure maximum performance with minimum down time.

The illustration shows a portion of the revamp gas recovery system of a large crude unit recently completed for SOHIO.

**The C. W. NOFSINGER Company**
Kansas City, Mo.


## Gulf Booklet Refutes Myths

Gulf Oil Corp., has begun distribution of a booklet entitled, "The Industry Nobody Really Knows," aimed at giving consumers of all petroleum products a more realistic understanding of how the oil industry actually gets its job done. The story is told in terms of the individual experiences of independent operators who have only a contractual relationship with any major oil company. The publication separates fact from myth in explaining how oil men who comprise "the largest industrial enterprise ever known," carry on their business.

Written by Craig Thompson, free-lance magazine writer and author, the collection of facts for this story involved more than 8,000 miles of travel and hundreds of hours of interviews.

"The mental picture of the large oil company as a sort of gigantic octopus feeding on the little fellows is a myth," Thompson says, pointing out and refuting three other myths about this business. These, he says, are that ownership of an oil well automatically makes a man a millionaire, that oil millionaires are created by a so-called tax privilege known as percentage depletion; and that the oil industry is dominated and controlled by a few big companies.

## Argentina Gets 71 Bids

Argentina has received 71 preliminary bids pursuant to the request made by the Aramburu government early in 1956 to American, West European, and Japanese oil equipment manufacturers for pipeline and refinery construction. Largest U. S. bid reported was from Williams Brothers Sudamericana Ltd., involving $200 million, 30 percent down and the rest in seven years. M. W. Kellogg Co., through its Italian, German, and French subsidiaries, submitted bids on refineries and other plants aggregating $40 million on seven-year terms. Bids covered a 24-inch, 1100-mile gas pipe line from Campo Duran oil field to Buenos Aires, a 12-inch 900-mile oil line from Campo Duran to San Lorenzo, a 12¼-inch, 620-mile crude line from Mendoza to San Lorenzo, a 34,000 barrels per day refinery at Buenos Aires, and several other plants, including a gas separator, asphalt, topping, and coking units.

Schneider Enterprises of France reportedly tendered a $15 million bid in the name of Compagnie Industrielle de Travaux. Argentina has said it will not consider bids with less than five year terms for repayment.

## Fluor to Seek Research

The Fluor Corporation, Ltd., has announced that its Research division will actively seek industrial contract research in the petroleum, chemical and petrochemical industries for the first time in the firm's 66-year history.

This step constitutes a departure for an engineering-construction company serving these industries to perform research work of this type. In the past, such activities have been handled by organizations devoted exclusively to research.

Fluor Research's position as a division of an engineering and construction organization affords an opportunity for evaluating a project and carrying ideas through to realities. The company's engineering and design specialists can also assist on individual research projects.

In keeping with the nature of the com-


For more data on advertising products, use Readers' Service Cards, last page.

*No need to guess about the physical properties of*

**JEFFERSON** mono di tri | ethanolamine

If you are interested in the physical properties of these versatile compounds, our technical bulletin will give you the information you seek. It describes graphically vapor pressure vs. temperature, boiling points of aqueous solutions, surface tension vs. temperature, specific gravity vs. temperature, specific heat vs. composition, freezing point vs. composition, and other properties.

In addition, you will find chemical and toxicological properties, methods of analysis, uses, and handling and storage information. Write today for your copy of Jefferson's Mono, Di, and Triethanolamine Bulletin. **Jefferson Chemical Company, Inc., Box 303, Houston 1, Texas.**

*Essential Chemicals from Hydrocarbon Sources*

**Jefferson**
CHEMICAL COMPANY, INC.
HOUSTON • NEW YORK • CHICAGO
CHARLOTTE • LOS ANGELES



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# Right from the start—

For more than forty years UOP has been the leading independent petroleum research organization. Over the years it has been responsible for the development of many of the most important refining processes now in use. The results of UOP research have always been made available to all refiners, anywhere in the world.

In cooperation with the technological and manufacturing staffs of these refiners the application of these processes has made a major contribution to the continuing betterment and marketability of petroleum products.

*Forty Years Of Leadership In Petroleum Refining Technology*

# Research is working to make petroleum products better

Throughout the great petroleum industry there are thousands of scientists, technicians, engineers devoting their efforts exclusively to research. Their efforts range from the development of an abstract theory in the laboratory to the practical application of it in the field or at the refinery.

Yet, right from the start, most everything that is done in petroleum research concentrates on the development of improved products from petroleum, products better fitted to answer the demand of today's economy, products that fill as well as anticipate the growing public need.

Research, too, is devoted to the task of helping the refining industry get the most out of every barrel of crude that is processed in its plants. This makes possible the economical manufacture of petroleum products and their availability to the broadest markets at reasonable prices.

We have a lot of these men of science here at Universal, and there are lots more on the research staffs of refiners everywhere. It is good to know that their efforts are concentrated on the continual improvement of petroleum products, a satisfying assurance that the oil industry will continue to fulfill its responsibilities.

**UNIVERSAL OIL PRODUCTS COMPANY**

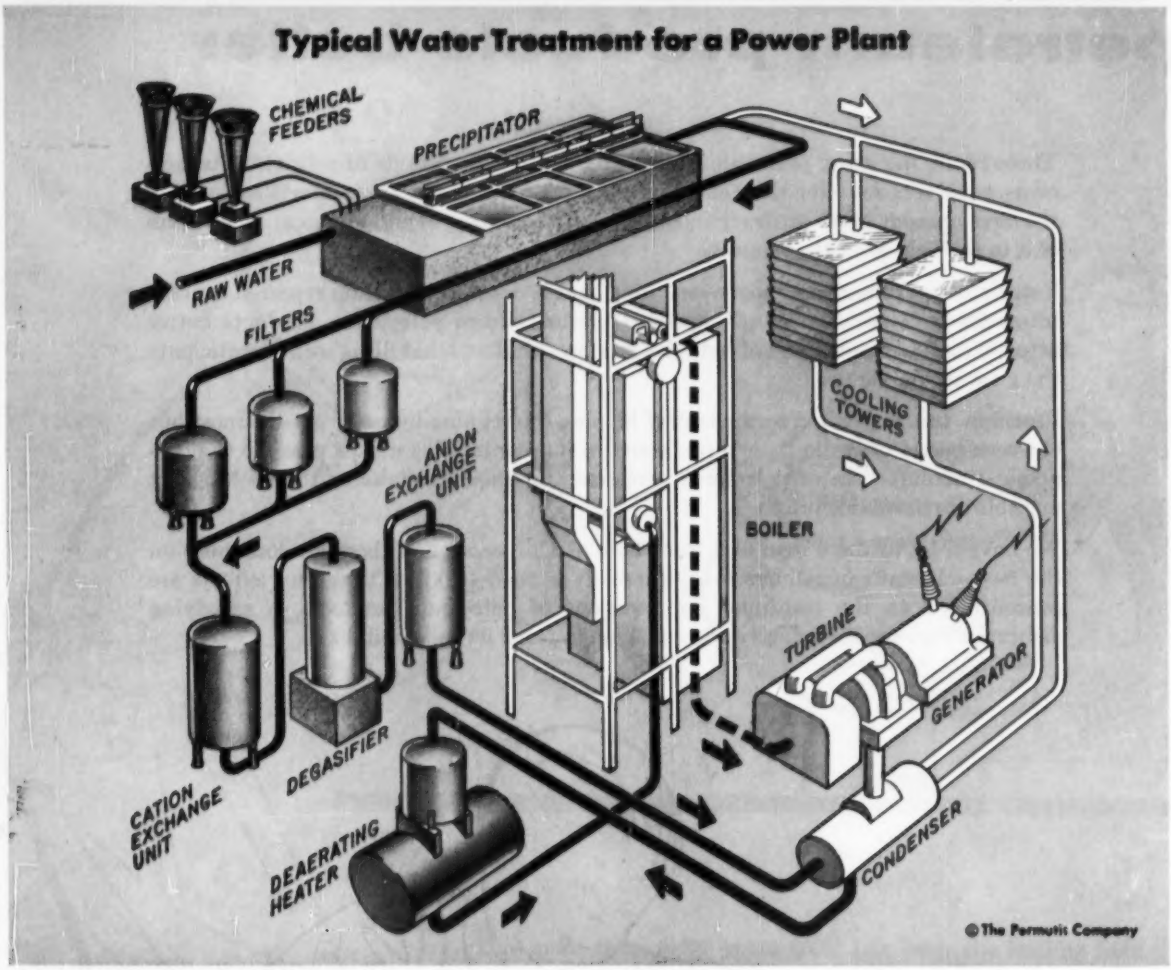
30 ALGONQUIN ROAD, DES PLAINES, ILLINOIS, U.S.A.



For more data on advertised products, use Readers' Service Cards, last page.

# WATER:

Modern power plants require "ultra-pure" water for their high-pressure boilers. To provide it . . . new equipment produces the equivalent of commercially distilled water . . . at far lower cost!




# 99.99998% Pure Water for Power

Ordinary water with just the dirt and hardness removed was good enough for old-time boilers. But today's efficient plants operate at high steam pressures . . . up to 2600 psi. Future plants will operate at 5000 psi. and up!

● **At high pressures** *any* mineral element in the water causes trouble. For example: The few parts per million of dissolved silica in practically all water, while harmless for drinking, builds up as a glass-like deposit on turbine blades . . . impairs the balance and efficiency of the turbine.

● **Simplified flow sheet** shows how a muddy river water might be conditioned: The **Precipitator,** with coagulants and other chemicals from the **feeders,** takes out mud, most suspended matter and hardness. (This clarified water is adequate for the cooling-water system . . . cooling tower, condenser.) Next—the **filters** remove final traces of suspended matter. The **cation exchanger** takes out metallic ions (calcium, magnesium, sodium, iron, etc.). The **degasifier** removes carbon dioxide (formed in the cation exchanger). The **anion exchanger** takes out chlorides, sulfates, etc. and silica. The **deaerating heater** preheats the water for the boiler and removes corrosive gases.

Depending on the condition of the raw water and the type of demineralizer, total solids are often reduced to less than 0.2 parts per million!

● **Oldest and largest** U. S. firm in the business, **The Permutit Company,** designs and builds complete water-conditioning systems like that shown above for leading utilities and industrial power plants. Other Permutit installations are reducing costs or improving products for almost any industry you can name. For advice on any water conditioning problem, simple or complex, write: The Permutit Company, Dept. PR-12, 330 West 42nd St., New York 36, N. Y.

**PERMUTIT®**

*rhymes with "compute it"*

**WATER CONDITIONING for BOILERS, PROCESSING, PUBLIC and HOME WATER SUPPLIES**

## What's Happening . . .

pany's business, Fluor Research specializes in the fields of chemistry, chemical engineering, physics and mechanical engineering. Within these fields, research projects range from laboratory experiments to economic evaluations, and include the design and operation of pilot units and the solving of plant problems. Generally, emphasis is on applied rather than basic research.

Over the past years, Research has done considerable work in the development and evaluation of new products, particularly in the fields of acoustics, mass and heat transfer, particle removal from gases, and other important fields.

### WPRA to Meet in Houston

The Gulf Coast Regional Technical-Industrial Relations Meeting of the Western Petroleum Refiners Association will be held at the Lamar Hotel, Houston, Texas, Feb. 7-8, 1957. The two-day meeting is the first of five regional meetings which the WPRA will conduct during 1957, and will be attended by refiners from Texas, Louisiana, Oklahoma and Arkansas.

The 45th annual meeting of the Western Petroleum Refiners Association will be held at the Hilton Hotel (formerly the Plaza Hotel), San Antonio, March 25-26-27, 1957.

### OCAW Seeks 12.5 Percent

The Oil Chemical & Atomic Workers Union hasn't specified yet what its wage hike target in the U. S. will be, but it is seeking a 12.5 percent increase in Canada. Other Canadian goals: shift differentials of 15 cents and 20 cents, double time for overtime, and premium pay for regular Sunday work for shift workers.

Several independent unions in U. S. have launched pay-increase drives ranging from 9 to 25 percent increases. (PETROLEUM REFINER, Nov. p. 265). OCAW, however, only wants "substantial" increase.

### Houston Charges Dismissed

Houston's air pollution battle has cooled off somewhat. County Attorney Burke Holman has entered a motion to dismiss Harris County's lawsuit against 53 ship channel industries. Only firm excluded from the dismissal motion: Tenn-Tex Chemical.

### Two Butadiene Plant Bids

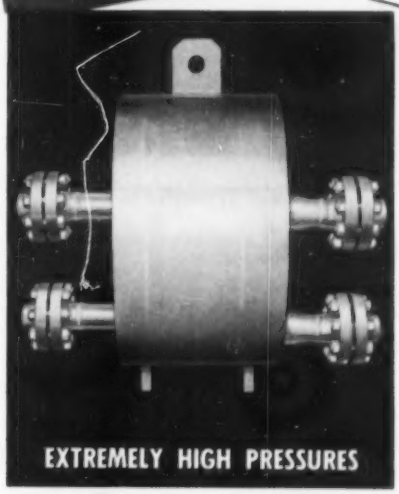
Bids for the leasing of the government-owned alcohol butadiene plant at Louisville, Ky., have been received by Federal Facilities Corporation from Publicker Industries, Inc., and from Union Carbide and Carbon Corp.

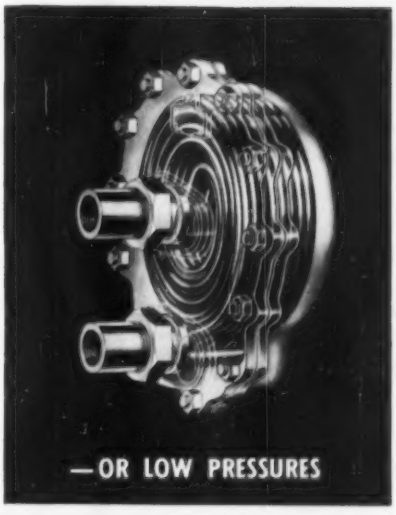
Negotiations with bidders will begin immediately and will be ended by Dec. 15. Attorney general must approve FFC recommendations, and the lease must be submitted to Congress for review.

Presently, the plant is under a three-year lease to Publicker, ending April 4, 1958.

### Octane Ratings Climb

Gasoline on sale at service stations in November increased to national weighted averages of 97.3 octane for premium and 90.3 octane for regular, according to the




OVER 100,000 HELIFLOW® Heat Exchangers

are giving the process industries

Higher rate of heat transfer

Closer temperature approach

Elimination of temperature strains

Compactness . . . smaller space requirements

and . . . Complete dependability

*Wouldn't it pay you to investigate?*

Graham

MANUFACTURING CO., INC.

415 LEXINGTON AVE., NEW YORK 17, N. Y.

Offices in all principal cities

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# DON'T BLOW YOUR TOP!

INVESTIGATE
**FOSTER**
RELIEF VALVES

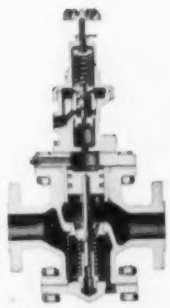
**LOOKING FOR A PRESSURE RELIEF VALVE TO DO A SPECIAL JOB? CHANCES ARE FOSTER HAS JUST WHAT YOU NEED.**

FOSTER Automatic Pressure Relief Valves are designed for industrial, power plant and marine applications requiring dependable, adjustable non-pop type of control, relieving excess pressure into a lower pressure system or to atmosphere.

Foster valves are built to last. They are designed to provide continuous protection and control of pressure for years of trouble-free service. Foster assures long-life by using materials suitable for specific operating conditions; bronze, stainless steel alloys and various types of trim are available.

Valves are designed with diaphragm or piston actuation depending upon the required services and regulations.

The Foster R-4 Relief Valve shown here is spring loaded, adjustable, with an internal pilot operated main valve. Single seated, tight closing and suitable for dead end service, it is designed for general service where practically instantaneous relief is required of the excess pressure with minimum build-up.



R-4 is only one of many standard Foster Relief Valves for all operating conditions and services

*For address of nearest Foster Representative, consult your Red Book, or get in touch with us direct, ask for Bulletin R101*

FOSTER AUTOMATIC VALVES

**FOSTER ENGINEERING COMPANY**
835 LEHIGH AVENUE, UNION, N. J.
- AUTOMATIC VALVES
- CONTROL VALVES
- SAFETY VALVES
- FLOW TUBES


## What's Happening . . .

latest monthly survey of antiknock quality compiled by Ethyl Corporation.

The premium average was 0.2 octane number above October and 1.2 octane higher than a year ago. The regular average was 0.1 octane higher than in October and 1.5 octane numbers above a year ago.

Average tetraethyl lead contents in November were 2.54 ml per gallon of premium gasoline and 2.18 ml per gallon of regular gasoline.

### OIIC Budget Slashed

API board approved budget of $2,612,910 for Oil Industry Information Committee for 1957 activities. This is a decrease of $582,090 from the 1956 allocation.

Bulk of this reduction will come from the advertising program, which will be restricted to jobber, dealer, and trade publications. In discussing this, OIIC said that it was not satisfied with the present program but it felt it was not getting its message across fully. Therefore, decision was made to discontinue popular media advertising until whole program can be studied.

### Changes In Ownership

**Colorado Oil & Gas Corp.** has reached an agreement with **Trinidad Petroleum Development Co.** Basis: Colorado Oil stock in exchange for T.P.D. shares. This will enable T.P.D. stockholders to retain interest in Trinidad operations and to acquire interest in Colorado Oil's U. S. and Canadian properties. Agreement is subject to approval of stockholders U. K., and Trinidad governments.

**Pacific Petroleum Ltd.** has acquired from **Excelsior Refineries, Ltd.** and individual holders, all issued and outstanding common stock of **X-L Refineries Ltd.,** which owns a 2,000-barrel a day refinery at Dawson Creek, B. C. Pacific earlier bought a major interest in X-L from Excelsior, the parent company. In return for X-L shares, Pacific will issue its treasury shares with a lump cash payment.

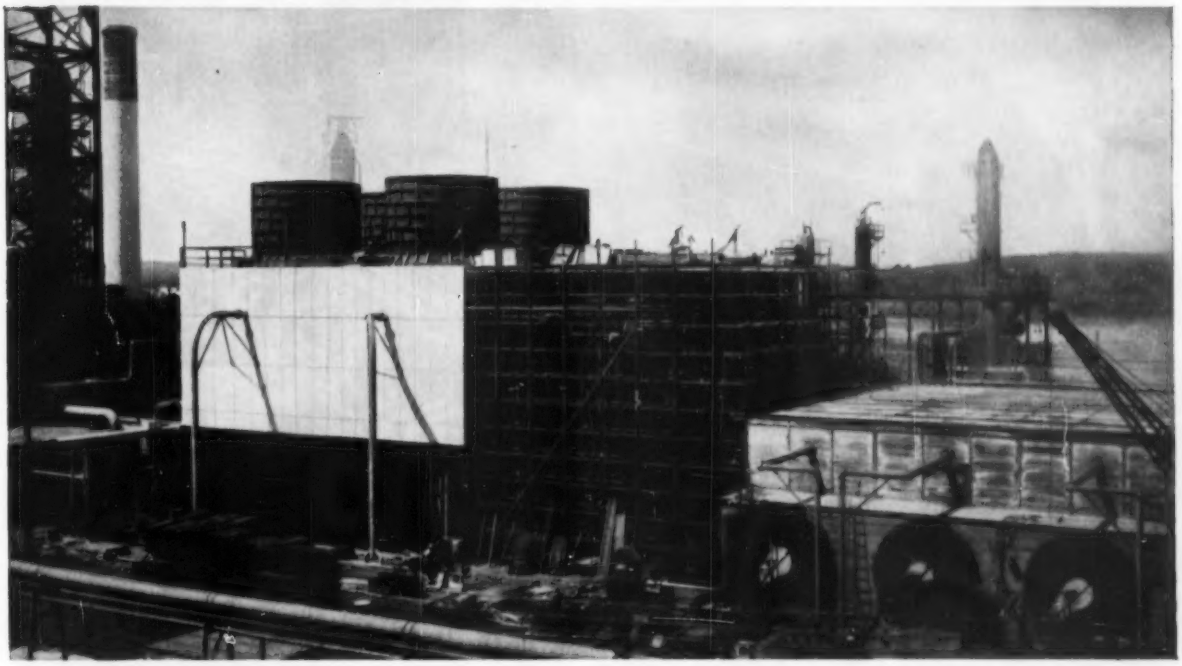
**Pennsalt Chemicals** and **Delco Chemicals, Inc.** Los Angeles, have approved a plan under which Pennsalt will acquire Delco. Acquisition will be accomplished through an exchange of stock. Delco's products will complement Pennsalt's specialty lines and will provide attractive opportunities for the upgrading of some of Pennsalt's basic heavy chemicals.

**Heyden Chemical Corp.** and **Newport Industries, Inc.** have approved a plan for the acquisition of Newport by Heyden. Heyden common stock will be exchanged in the ratio of 1½ shares for 1 share of Newport and the assumption of Newport's liabilities. Plan is subject to the approval of 2/3 of common stockholders of Newport and a majority of Heyden's common stockholders. Heyden's name will be changed to Heyden Newport Chemical Corp.

**Pacific Northwest Pipeline Corp.,** has signed an agreement with **El Paso Natural Gas Co.** to submit an offer


For more data on advertised products, use Readers' Service Cards, last page.

# MORE COLD WATER for D-X Sunray



## New FW Cooling Tower replaces original forced-draft installation—gives 80% more cooling capacity on same foundation

A NEW eighteen cell Foster Wheeler induced draft cooling tower is shown at the left, above, during construction at the West Tulsa refinery of D-X Sunray Oil Company.

The tower was built in sections over the basin previously used for a Foster Wheeler forced draft tower shown at the right. New cells were put on stream as completed and the remaining cells of the old tower continued to operate until demolished. In this way the heat load was carried successfully through the summer without any shut-down during erection.

The new induced draft cooling tower, occupying the *same* ground area, has 80% more cooling capacity than did the original forced draft installation.

The high cooling efficiency, low drift losses and rugged, all-redwood construction of the completely new line of FW induced draft cooling towers mean lasting economy and dependability in year-round service.

For complete information, send for a copy of new Bulletin No. CT-56-11. *Foster Wheeler Corporation, 165 Broadway, New York 6, N.Y.*

# FOSTER WHEELER

NEW YORK • LONDON • PARIS • ST. CATHARINES, ONT.



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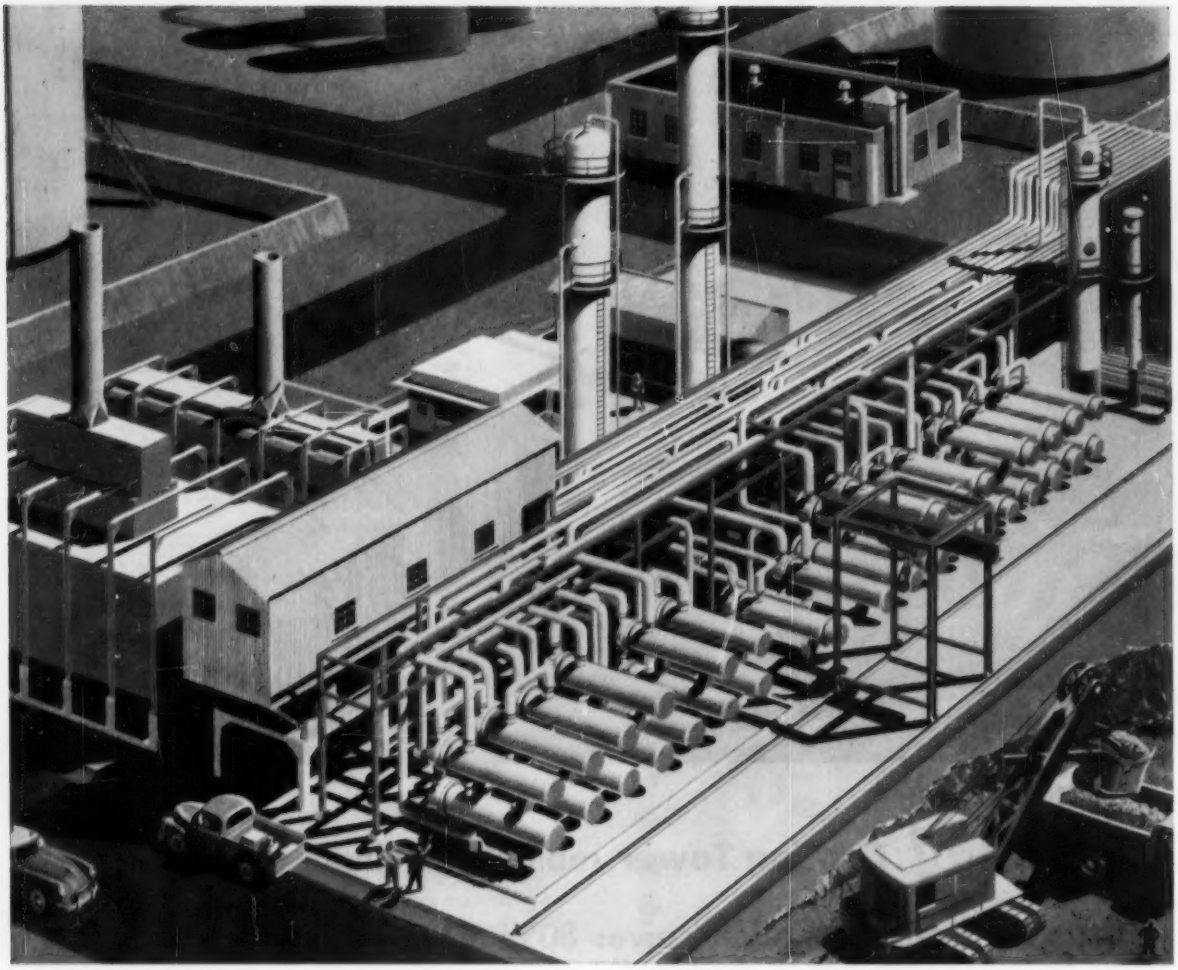


# not one... but two 15,000 b/d CATFORMERS for ATLANTIC

Blaw-Knox is designing and constructing two Catformers and Unifiners for THE ATLANTIC REFINING COMPANY. One to be installed in their Philadelphia refinery, the other for Atreco, Texas.

The units are identical, each having a reforming capacity of 15,000 barrels per day.

To save both construction time and costs, this project was planned to take advantage of the engineering work for the first unit by adapting it directly to the second installation.

The background and experience of Blaw-Knox engineers in catalytic reforming and hydrogen treating, as well as other petroleum processes, are available to you in your expansion or new refinery plans. We welcome the opportunity to make recommendations.

50th Anniversary
BLAW-KNOX
1906-1956

**BLAW-KNOX COMPANY** Chemical Plants Division

Pittsburgh 30, Pennsylvania • Chicago 1, Illinois

Birmingham, New York, Philadelphia, San Francisco, Washington, D. C.



For more data on advertising products, use Readers' Service Cards, last page.

## What's Happening. . .

to stockholders Pacific Northwest, of an exchange of shares of the two companies. Pacific stockholders would be given seven shares of El Paso common stock in exchange for eight shares of stock in Pacific. If deal is completed, El Paso would get Pacific's pipeline from the San Juan Basin to the Northwest. Pacific owns 70 percent of Northwest Production Corp., 25 percent of Westcoast Transmission Co. and 49 percent of Phillips Pacific Chemical Co. which is completing an ammonia plant near Pasco-Kennewick, Wash.

## MEETINGS CALENDAR

| | |
|---|---|
| DEC. 13–14 | Air Pollution Conference, sponsored by Armour Research Foundation, Congress Hotel, Chicago. |
| JAN. 16–18 | Society of Plastics Industry, Annual Technical Conference, Sheraton-Jefferson Hotel, St. Louis, Mo. |
| 21–25 | American Institute of Electrical Engineers, 1957 Winter General Meeting, Hotel Statler, New York City. |
| 23–25 | Instrumentation for the Process Industries Symposium, Texas A & M College, College Station, Texas. |
| 28–30 | Eighth Plant Maintenance and Engineering Conference, Statler Hotel, Cleveland. |
| 31–Feb. 1 | Sixth Annual Instrument Short Course, Los Angeles Harbor Junior College, Wilmington, Calif. |
| FEB. 4– 8 | American Society for Testing Materials Committee Week, Benjamin Franklin Hotel, Cleveland. |
| 5– 7 | Twelfth Annual Technical and Management Conference of the Reinforced Plastics Division of The Society of the Plastics Industry, Inc., Edgewater Beach Hotel, Chicago. |
| 7– 8 | Gulf Coast Regional Technical-Industrial Relations Meeting of the Western Petroleum Refiners Association, Lamar Hotel, Houston. |
| 10–16 | ASTM Committee Meeting on Petroleum Products, New Orleans. |
| 19–20 | Chemical Market Research Association Meeting, New Sheraton Hotel, Philadelphia. |
| 22 | Natural Gasoline Association of America, Permian Basin Regional Meeting, Scharbauer Hotel, Midland, Texas. |
| MAR. 3– 6 | American Institute of Chemical Engineers, Greenbriar Hotel, White Sulphur Springs, Virginia. |
| 4– 8 | Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy, Penn-Sheraton Hotel, Pittsburgh. |
| 10–13 | American Institute of Chemical Engineers, Greenbriar Hotel, White Sulphur Springs, Va. |
| 11–15 | Nuclear Congress, Convention Hall, Philadelphia. |
| 18–21 | Society of Plastics Industry, Annual Conference and Pacific Coast Plastics Exposition, Shrine Exposition Hall, Los Angeles. |
| 25–27 | Western Petroleum Refiners Association, 45th Annual Meeting, Hilton Hotel, San Antonio, Texas. |
| 27–29 | American Power Conference, Annual Meeting, Sponsored by Illinois Institute of Technology, Hotel Sherman, Chicago. |
| APRIL 2– 4 | Corrosion Control Short Course, University of Oklahoma Extension Study Center, Norman. |
| 7–12 | American Chemical Society, 131st Annual Meeting, Miami, site unreported. |
| 8–12 | American Welding Society, Spring Technical, National and Welding Show, Sheraton and Bellevue-Stratford Hotels, Philadelphia. |
| 16–18 | National Petroleum Association, Semi-Annual Meeting, Cleveland Hotel, Cleveland. |

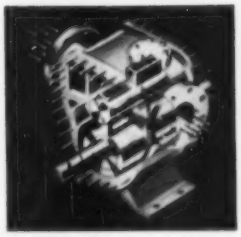

**Regardless of Viscosity . . .**
**DELIVERY—AS SPECIFIED!**

Kinney®

**Heliquad and Rotating Plunger Pumps combine Versatility with Reliability!!**

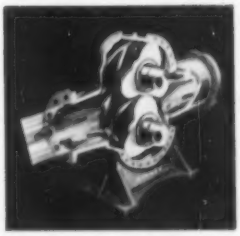
**The viscosity and lubricating qualities** of the liquid to be handled should be prime considerations in proper pump selection. These two factors were vital in the development of the two basic liquid pump designs that Kinney offers in a wide variety of types and sizes. The *rotating plunger* pumps are designed to handle viscous fluids having lubricating qualities sufficient for internal bearings and working parts . . . while *heliquad pumps* (with external bearings) pump non-viscous liquids with little or no lubricating qualities (water, gasoline, hot oils, and similar liquids). Various types of drives, speed reducers, rotors (for heliquads), etc., are available to suit service requirements. Features contributing to long life, high efficiency, and application flexibility include: oversized suction and discharge openings, larger shafts and bearings, conservative capacity ratings, external anti-friction bearings, etc. Request complete details.

**MODEL SD ROTATING PLUNGER PUMP**



For viscous fluids (asphalts, heavy oils, grease, emulsions, acid sludge, etc.) . . . can be used to meter or proportion fluid pumped. No valves, blades, springs, or vanes. Models range from 1½ GPM to 500 GPM and working pressures from 70 to 250 psi.

**MODEL HQ HELIQUAD ROTARY PUMP**



Unique heliquad rotors assure continuous, non-pulsating fluid delivery over a wide viscosity range (from gasolines or solvents to heavy oils or residuals). Bearings and timing gears external to pumping chamber. Capacities up to 2500 GPM and pressures up to 300 psi.

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Write today for your copy of Bulletin L51A which describes the complete line of Kinney Liquid Pumps . . . or contact one of our competently staffed offices in Baltimore, Charleston, W. Va., Charlotte, N. C., Chicago (La Grange), Cleveland, Detroit, Houston, Los Angeles, New Orleans, New York, Philadelphia, Pittsburgh, San Francisco . . . or The International Sales Office, 90 West St., New York 6, N. Y.

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For more data on advertising products, use Readers' Service Cards, last page.

# What's Happening . . .

## . . . *Among Men* in the Industry

**Robert N. Johnson** has been appointed chief technologist of the Avon Flying A Refinery of Tidewater Oil Co., Associated, Cal. He replaces **Harold J. Maddock** of Concord who has been transferred to the company's electronic data processing study group.

Johnson

Johnson will supervise blending of refinery products, preparation of supply and demand forecasts of crude oil and products, and technical investigation of products and processes.

Following graduation from the University of Washington with a B.S. degree in chemical engineering Johnson joined Tidewater as a junior chemist in 1946. His most recent assignment has been as operating foreman of the refinery's solvent and light oil treating plants.

**Paul A. White** has been appointed manager of the lubricating department of Socony Mobil Oil Co., Inc. He succeeds **P. W. Judah**, who was earlier named manager of the newly-created petroleum chemicals department.

White started with Socony Mobil in 1937 as an industrial sales engineer. Then followed promotions to sales supervisor, chief engineer of the Wadhams division, and to division industrial manager. In 1955 he was appointed manager of the engine builders division in the lubricating department.

**Alec H. Cook,** assistant supervisor of employe relations for Tidewater Oil Company's eastern division, has retired following 42 years of service.

Cook joined Tidewater in 1914, in the mechanical cost department at the company's Bayonne, New Jersey refinery. He was transferred to the New York office in 1930 as assistant director of personnel, the post he held under a new title.

**Albert Schrage** has joined the product development department of the chemical division of Celanese Corporation of America. He was formerly employed by Hudson Foam Plastics Corporation and prior to that worked in the production department of Celanese's chemical division. He is a 1949 graduate of Notre Dame University.

**L. C. Rowson** has been named assistant manager for the west coast of The Texas Company's liquefied petroleum gas sales division. This now extends Texaco's LPG sales division to include the west coast for the first time.

Rowson has been with The Texas Company since 1924, and since 1928 has handled the sale of LPG products on the west coast for Texaco's producing department.

**Dr. Robert Roy White,** professor of chemical engineering at the University of Michigan, has been named recipient of the 1956 Professional Progress Award in Chemical Engineering of the American Institute of Chemical Engineers. The award was to be presented to Dr. White at the 49th Annual Meeting of the AIChE in Boston Dec. 9-12.

A 1936 graduate of Cooper Union with a degree in science, and an M.S. and a Ph.D. from the University of Michigan, Dr. White had wide industrial experience before joining the University of Michigan in 1942. He has been active in research and is the author of 60 technical publications.

In 1946 he received the Junior Award from AIChE for his contributions to chemical engineering literature. He also received the Russell Award at the University of Michigan in recognition of his promise as a young teacher.

**S. W. Darling** has been appointed superintendent of The Texas Company's West Tulsa Works, to succeed **E. M. Reynolds**, who has retired after 43 years service. Also, **J. J. Rasor,** special representative for liquid petroleum gas sales at Tulsa, has been appointed assitant superintendent of the West Tulsa Works to succeed Darling.

Darling, assistant superintendent of the West Tulsa Works since September, was born in Checotah, Okla.

**O. V. Tracy** has been elected a vice president of Esso Standard Oil Co. He will continue to serve as a member of Esso Standard's board of directors, a post he has held since January, 1954. Since May of this year he has been a member of the company's executive committee, with board-level responsibility for both the manufacturing and chemical products departments.

Tracy

Tracy was general manager of chemical products from 1949 until last January, when he relinquished that post to give full time to his duties as a director. He has been associated with the development of synthetic rubbers, alcohols and other chemical products from petroleum since he joined Esso Standard in 1930.

**George C. Ellis** has been appointed a senior vice-president of Stauffer Chemical Co. and general manager of the West End Chemical Co. division. He has also been elected to the board.

Ellis was one of the original organizers of West End Chemical Co. and has been

### *Citation Awarded to Standard's Hughes*

**Dr. Everett C. Hughes, Manager of research in the Manufacturing department of The Standard Oil Company (Ohio), left, being presented citation of merit from the Chemical Profession in Cleveland, by Toastmaster Dr. Frank J. Zvanut, sales engineer, White Pigments division, Godfrey L. Cabot, Inc.**

# *the BIGGEST NEWS in expansion joints since the equalizing ring*

**New Zallea Duo Equalizing Expansion Joints** represent a major advance in expansion joint design. Years of continuous research have resulted in an expansion joint that lasts longer, is substantially smaller and lighter, and has greater stability than any other available expansion joint.

**Longer life.** Hundreds of cycling tests to destruction prove that Duo Equalizing Expansion Joints last as much as 40% longer than Self Equalizing Expansion Joints at the same pressure and movement.

**Lighter weight.** Weight of the expansion joint has been reduced as much as one-third. Handling and installation are easier.

**Shorter length.** Overall length has been reduced as much as 30%.

**Greater stability.** Reduction in ratio of length to diameter means higher stability at high test pressures —no need to support the expansion joint to prevent buckling during hydrostatic testing.

**Sizes and traverses.** Sizes range from 3″ diameter to 72″ diameter, for traverses up to 7½″ in a single unit or 15″ in a double unit.

**Working pressures.** Although normally intended for 150 and 300 psig working pressures, Duo Equalizing Expansion Joints can be designed for higher pressures.

**Service.** The Duo Equalizing Expansion Joint is preferred for all outdoor piping systems subjected to atmospheric temperature changes—as well as for institutional and other services that operate on frequent on and off cycles.

**Get the complete story** of the new Zallea Duo Equalizing Expansion Joint in our newly published 72-page Zallea Expansion Joint Manual. Write today, on your Company letterhead, for your copy of Catalog 56. Zallea Brothers, 890 Locust Street, Wilmington 99, Delaware.

*Zallea*
*expansion joints*

Zallea Brothers, Wilmington 99, Delaware • World's largest manufacturer of expansion joints

## Men in the Industry . . .

an officer and director for the past 26 years, serving as president since 1943.

Stauffer also announced **H. D. Hellmers,** formerly vice-president in charge of production for West End Chemical, as Stauffer production vice-president. **D. G. Ellis,** West End's sales manager, has been appointed Stauffer sales vice-president.

**C. H. Whitman,** manager of Esso Standard Oil Company's crude oil purchasing department, Shreveport, and a member of the management committee of the company's Louisiana Division, retired December 1.

A native of Louisiana, Whitman has been associated with the Esso company for almost 42 years. He began his service in 1915 at the Baton Rouge refinery.

**Dr. Harold E. Achilles** has been appointed asistant manufacturing coordinator at Tidewater Oil Company's New York divisional office. The following were appointed to posts at the Delaware Flying A refinery: **C. A. Phillips,** supervisor of the desulfurizing and hydrogen area; **Robert C. Harms,** general coordinator of zone 1; **George E. Rohrmann,** general coordinator of zone 3; **John J. Dudowicz,** electrical coordinator; **Samuel E. Roth,** instrumentation coordinator; **George S. Lee, T. Northcutt, James S. Whittey** and **George N. Haines,** night superintendents.

Dr. Achilles joined Tidewater in 1936 as a research chemist. He was named technical service supervisor of the research department in 1944, and held that post until his present appointment.

**Winthrop M. Barnes** has joined Southwest Research Institute's industrial economics staff as process engineer and will advise companies and communities on industrial development.

Barnes came to San Antonio from the R. M. Hollingshead Corp. of Camden, N. J., where he was manager of market development. His experience includes eight years as a chemical engineer with a background in research, production, pilot plant and design work, and eight years of administration in market analysis fields.


On ungrounded 440 v. 3-phase systems
THIS ELECTRONIC DEVICE
GIVES YOU AUDIO-VISUAL....
WARNING

....before those hidden grounds become dangerous and costly!

By warning of trouble before it becomes serious, the DELTA-DESCO GROUND ALERT saves in many ways. Saves expensive motor rewinding, switch gear and transformers, and prevents crippling shut-downs.

At the same time it reduces the possibility of fire hazards and personnel injury.

HOW IT WORKS! When ground resistance drops to 7,500 ohms in any phase of the 440 V. 3-phase ungrounded circuit, the *green light goes off,* a bell inside the instrument starts to ring and the *red light comes on.* The bell continues to ring until switched off and the red light burns until the ground is corrected. As long as all phases are ground-free the green light burns. Available in portable or stationary model.

Don't wait until trouble strikes . . .

DELTA-DESCO *Electronic* GROUND ALERT

WRITE FOR DESCRIPTIVE BOOKLET -TODAY!

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**T. M. Newsom** has been promoted to senior chemical engineer and **C. L. Thorpe** to senior research chemist in technical and research divisions at Humble Oil & Refining Company's Baytown refinery. Newsom holds a B.S. degree in chemical engineering from The University of Texas and Thorpe, a B.A. degree in chemistry from Cornell College (Iowa).

**Edd R. Turner,** president of Pan American Production Co., Houston, has retired. Turner was the first employe of Pan American when that company was formed in July, 1935. He was the company's first general manager, was made vice president in 1939, first vice president in 1945 and was named president in 1947. Pan American will be merged (later this year) with Stanolind Oil and Gas Co.

Turner

Turner has been in the oil industry for 41 years, having started his career with The Texas Company in 1915. In 1929 he resigned to become assistant to the production vice president of Continental Oil Co. at Ponca City, Okla. In 1935 he joined Pan American.

**Theodore A. Burtis** has been elected president and chairman of the board of directors of Houdry Process Corp., and has been named a director of the corporation's subsidiary, Catalytic Construction Co.

Burtis succeeds **C. G. Kirkbride,** who is joining the Sun Oil Co. but will continue his association with Houdry as a member of the board of directors. Both men take up their new duties December 1.

Burtis received his B.S. degree in chemical engineering from Carnegie Tech in 1942 and his M.S. degree in chemical engineering, from Texas A. & M. in 1946. Before joining Houdry, he worked for Magnolia Petroleum Co. and Owens-Corning Fiberglas.

**E. W. Patterson,** formerly manager of Suntide Refining Co., has been elected vice president in charge of marketing.

**Harry D. Hancock** has been elected president of Cities Service Gas Co., succeeding **Glenn W. Clark,** who recently resigned to accept the presidency of Mississippi River Fuel Corp. The board also created the new post of executive vice


For more data on advertising products, use Readers' Service Cards, last page.

*Another client benefits from a Badger "Precious Plus"*

## An Achievement of Creative Engineering:

# STYRENE FROM GASOLINE!

Sketch shows Cosden Petroleum's new ultra-fractionation and styrene manufacturing plant as it will appear when completed in early 1957. The four columns — each almost 200 feet high —will be among the tallest ever erected!

## The plant that "couldn't be built" now under construction

At Cosden's Big Spring, Texas, refinery, Badger is erecting the first plant ever designed for the recovery of ethyl benzene by distillation. The process *first* became commercially practical when Badger Engineers developed Ultra-fractionation.

Now, instead of marketing catalytic reformer effluents as mixed solvents, this new distillation process will make it possible for the client to produce a pure product with a far higher profit margin.

This achievement in *Creative Engineering**, like all intangibles, can never be shown on the blueprints. Yet it is the "Precious Plus" in Badger's performance that is making Cosden's plant possible!

Other leading companies, too, find Badger's *plus* in performance of precious advantage — whether their need is design, engineering or construction. How else explain the unusual growth Badger is enjoying?

**+ You need new "yardsticks" to measure the plus performance of Badger.** For the abilities of this dynamic organization go far beyond what can be shown on blueprints—and it's such intangibles that add up to better processes and plants, faster and at lower cost.

***Creative engineering** . . . whether your process problem is common or complex, Badger engineers solve it with fresh thinking that frequently produces new efficiencies, unexpected savings.

**Broad experience** . . . Badger Engineers are more than competent—most staff members are recognized authorities in their fields.

**Key Man operation** . . . the Badger man who submits your proposal is always a principal—always the Key Man responsible for the execution of your job. Clients say, "This is the Badger difference that makes the difference."

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STRAHMAN VALVES, Inc.
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## Men in the Industry . . .

president, to which **Kirby E. Crenshaw** was elected.

Hancock is known for his contributions to the growth of the natural gas industry and for his work in the development of high-pressure, large-diameter pipe lines for long-distance transportation of natural gas. He received the American Gas Association Distinguished Service Award in 1947 and its Award of Merit in 1953.

Crenshaw began his career with Cities Service in 1930 at Bartlesville, Okla., as a junior engineer, and after various promotions, became vice president of Cities Service Gas Co. in 1947.

**L. W. Witte,** traffic manager for D-X Sunray Oil Co., has retired after 39 years service, and will be succeeded by **H. C. Lechner,** formerly assistant traffic manager.

Witte joined the company in 1917 as rate and utility clerk. He was named traffic manager in December, 1947, after serving as asistant traffic manager for a period of years.

Lechner's employment started in 1926 as rate clerk in the traffic department. He became chief clerk in 1929 and was named assistant traffic manager in 1941.

**John J. O'Connell** has been appointed marketing vice president of Amoco Chemicals Corp., which will be formed before the end of the year through consolidation of three chemical affiliates of Standard Oil Company (Indiana). (PETROLEUM REFINER, November, p. 266.)

O'Connell has joined the Chicago offices of **Jay H. Forrester,** Amoco Chemicals president-elect. Forrester also announced that **Dr. John W. Bertetti,** who will be vice president in charge of manufacturing, has joined the Chicago offices.

O'Connell is a graduate of the University of Illinois where he received his master's degree in organic chemistry in 1938. He also studied at Columbia University, Brooklyn Polytechnic, and New York University. He received a master's in business administration last year at NYU.

**Lloyd E. Lundahl,** Memphis, Tenn., has been named chief engineer and assistant maintenance superintendent for Great Northern Oil Co., Pine Bend, Minn.

Lundahl

For the past two years Lundahl has been assistant chief engineer in charge of design and construction of plant facilities for Grace Chemical Co., Memphis.

Previously he was in the refinery engineering and construction division of Bechtel Corp., San Francisco, and Shell Chemical Corp., Houston.

**John W. Lane,** automotive manager, lubricating department, Socony Mobil Oil Co., Inc., was elected president of the National Lubricating Grease Institute at the organization's 24th annual meeting in Chicago. He succeeds **W. M. Murray,**

LITHIUM METAL AND ALLOYS
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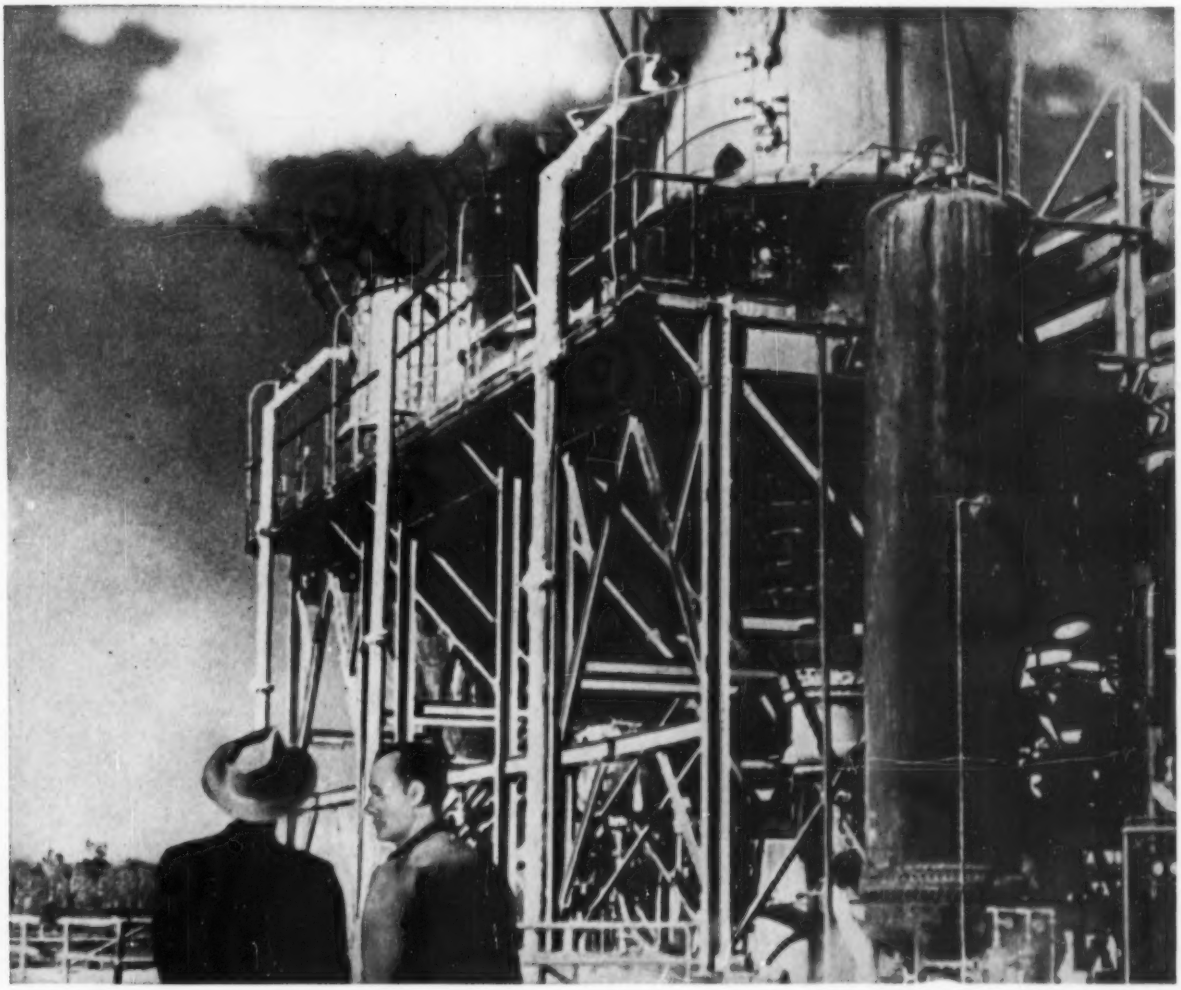

Photo courtesy of Lion Oil Company, El Dorado, Ark.

# A switch to type 316 Stainless Steel adds years to life of ammonium sulfate process equipment

Know what the two men are talking about?

**The saturators.**

Time was when they were made from carbon steel lined with a non-ferrous material. But this construction couldn't take the 5-6% free sulfuric acid . . . the 140°F. temperatures . . . the erosive attack of fast-moving gas bubbles.

**Failed all too soon.** So . . .

The engineers switched to type 316 austenitic chromium-nickel stainless steel; switched to type 316 for pipes, pumps and crystallizers as well.

**Result?** With type 316, the equipment has been in continuous service for four years and *still* is in good condition.

There are good reasons why stainless steel is so widely used in process equipment:

1. It resists a wide variety of oxidizing acid conditions.
2. It resists creep, scaling or oxidation at elevated temperatures . . . retains toughness at low temperatures.

There's a wide variety of stainless steels to choose from. Each is specific for a certain type of operating condition. We will be happy to suggest the right one for you. Just write.

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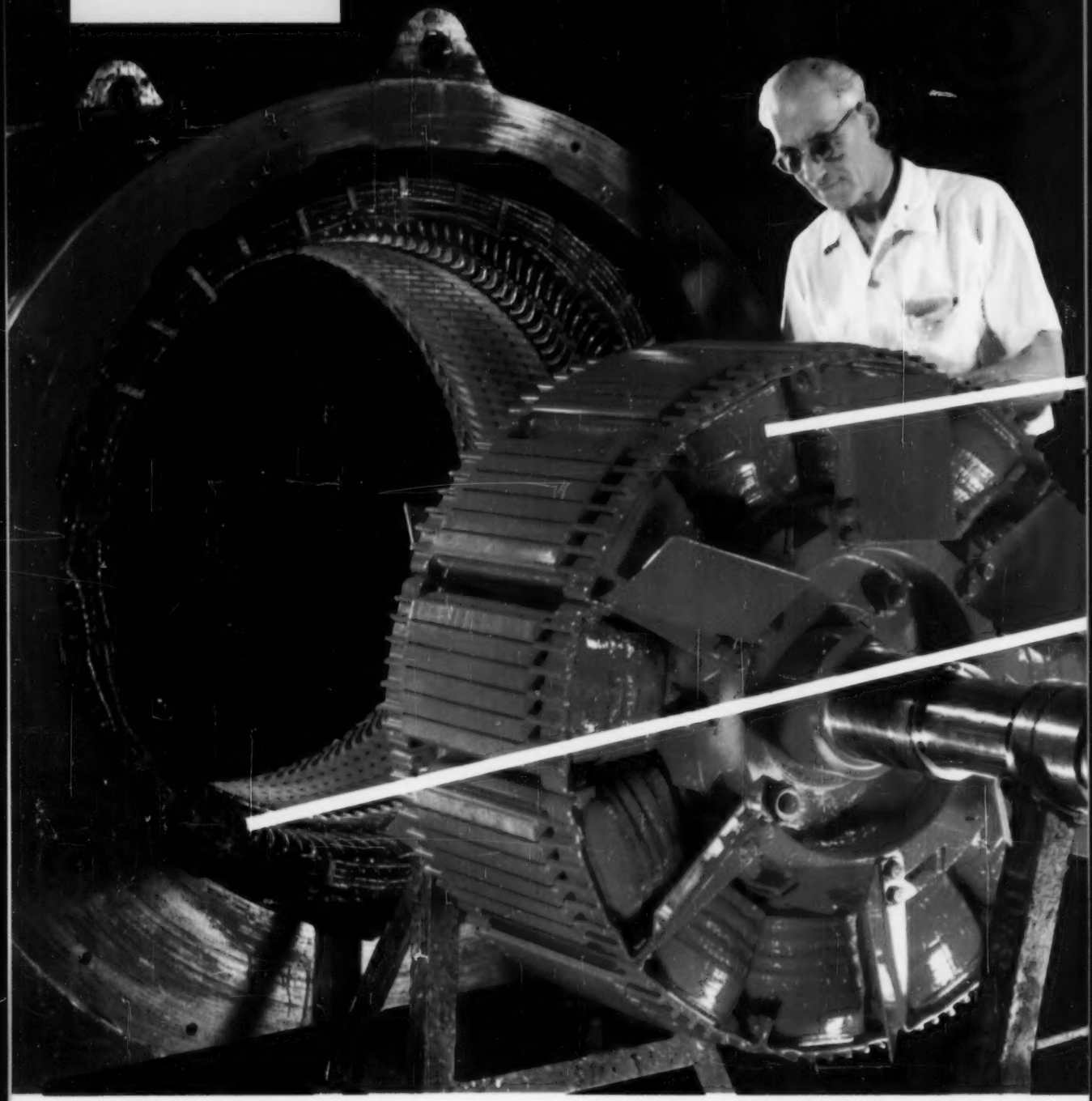

ALLIS-

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## New Integrated Field Coils Plus *Silco-Flex* Stator Insulation Provide Superior Motor Protection . . . Under Any Operating Conditions

1

**Integrated Field Coils** are bonded in heat-stabilized resins, enclosed in a resin-impregnated sheath of oriented glass fibers and bond-locked on the pole structure . . . dimensionally stable to withstand heating and thermal shock, vibration and fatigue at elevated temperatures . . . sealed throughout against atmospheric contaminants and fully protected against destructive forces.

2

***Silco-Flex* Insulation** provides a homogeneous, void-free insulating wall of silicone rubber on stator coils. It is unexcelled in life and thermal stability at high temperatures . . . resistant to most chemicals, water, weather . . . outstanding in flexibility and resilience . . . able to withstand abrasion and corona . . . resistant to physical and mechanical forces.

**Exclusive Allis-Chalmers "double protection"** is available on large electrical machines with operating temperatures through Class B range.

*Silco-Flex* is an Allis-Chalmers trademark.

**For more information** on these quality insulation systems contact your nearby A-C office, or write Allis-Chalmers, Power Equipment Division, Milwaukee 1, Wisconsin for Integrated Field Coil Bulletin 05R8525 and *Silco-Flex* Insulation Bulletin 05R8341.

*Allis-Chalmers "Double Protection," with integrated field coils and Silco-Flex stator coil insulation, adapts this 600-hp, 2300-volt, 600-rpm synchronous motor to the most severe operating conditions.*

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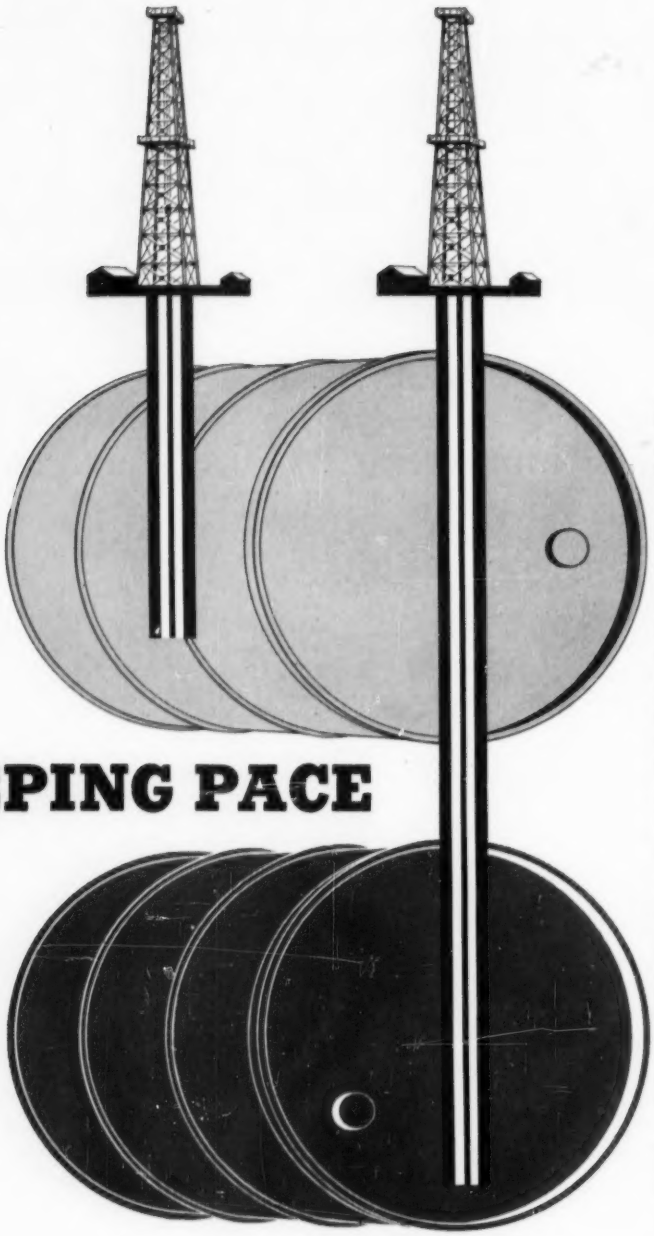

# KEEPING PACE

Drills were chewing their way down for about 2000 feet in the search for oil in 1916. Today's drilling depth is more than double that.

The change in drilling that forty years has brought well symbolizes many advances in the petroleum and chemical industries. Engineers have dug more deeply into the secrets of nature, too . . . have designed plants and processes to wrest new products and services from petroleum, ores and elements.

We mentioned 1916 because that is the year Sun Ship was founded. It has long served the swift-growing needs of petroleum and chemical industries. Year by year, the engineering skill and facilities of the great Sun Ship plant have proven their ability to meet the demands for plant and equipment keyed to the swift pace of progress in these and other important fields. Sun Ship keeps pace with progress.

**Sun**

**SHIPBUILDING & DRY DOCK COMPANY**

SINCE 1916

ON THE DELAWARE • CHESTER, PA.

## Men in the Industry . . .

Kerr-McGee Oil Industries, Inc., Oklahoma City.

**Rudolph Cubicciotti,** vice president, L. Sonneborn Sons, Inc., New York, was elected vice president, and **A. J. Daniel,** Battenfield Oil and Grease Corp., Kansas City, Mo., was reelected treasurer. **Thomas W. Miller,** Kansas City, was reappointed executive secretary.

Herget

Parker

**Walter T. Herget** has been promoted to a newly created position of manager of operations in the manufacturing department of American Oil Co. He will be assisted by **H. A. Parker,** former technical director of the Destrehan, La., refinery, who has been promoted to the new position of assistant manager of operations.

Herget, who has 14 years service with the company, has assisted Yorktown refinery manager **Mark C. Hopkins** in staffing and training permanent employees since August, 1955. He was born in Pekin, Ill., and graduated from the University of Illinois with a degree in chemical engineering.

Parker graduated in 1944 from Cornell University. He entered the oil industry as a process design engineer in the research department of the Whiting, Ind., refinery of Standard Oil Company (Indiana). After being promoted to a group leader in process design in 1946, he was transferred to Pan-Am Southern Corporation's Destrehan, La., refinery as technical director in 1951.

Herget will be succeeded as assistant manager at Yorktown refinery by **Brady V. Tunnell** who went to Yorktown last fall as superintendent of the operating department of the new refinery. Tunnell, who has 16 years of company service, will be succeeded by **Guy L. Honeycutt,** with 17 years service, who has been general operating foreman at Yorktown. Both Tunnell and Honeycutt graduated from the University of Texas.

**Chalmer G. Kirkbride** has joined Sun Oil Co., as executive director of the research, patent and engineering departments. In accepting the new position at Sun, Kirkbride resigns as president and chairman of the board of directors of Houdry Process Corp., Philadelphia.

Also **Dr. Charles L. Thomas** has been appointed director of the research and development department. Dr. Thomas, formerly associate director of research and development, replaces **Dr. J. Bennett Hill** who has retired.

Kirkbride, who was born in Tyrone, Oklahoma, in 1906, obtained his B.S. and M.S. degrees in chemical engineering at the University of Michigan in 1930. He was the recipient of the professional progress award of the American Institute of

Centrifugally Cast Pipe is STRONG Pipe.....

Planning to install high pressure lines in your plant? Will they carry hot corrosive liquids or gases?

You will find SAFETY in DURASPUN Centrifugally Cast Pipe. It's very strong, with strength approaching that of forged steel. It can be alloyed to give you maximum resistance to the heat and corrosion to be encountered.

.it's alloyed to resist corrosion and high temperature

DURASPUN Pipe comes in a wide range, as follows:

| Outside Diameter | Minimum Wall | Length |
|---|---|---|
| 2½" to 3" | 1/4" | 88" maximum |
| 3" to 6" Inclusive | 5/16" | 110" maximum |
| Over 6" to 12" Inclusive | 3/8" | 168" maximum, 24" minimum |
| Over 12" to 14" Inclusive | 7/16" | 168" maximum, 24" minimum |
| Over 14" to 20" Inclusive | 1/2" | 180" maximum, 48" minimum |
| Over 20" to 24" Inclusive | 1/2" | 88" maximum |
| Over 24" to 32" Inclusive | 5/8" | 80" maximum |

This is standard piping. Special cylindrical shapes in comparable high alloy steel can be cast centrifugally . . . retorts, furnaces, fractionaters and other such equipment come in this class.

Write us about your requirements. Our metallurgists backed by thirty-five years of experience will be glad to help select the best combination of alloying elements to take care of your operating conditions.

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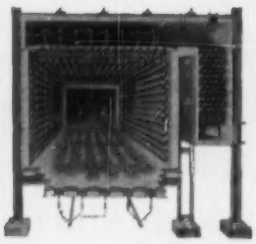
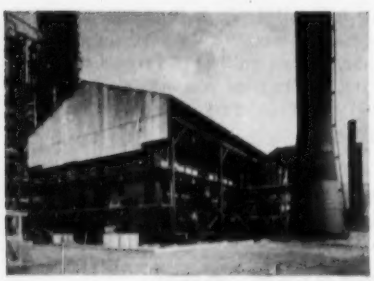
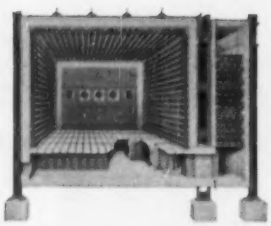
OIL HEATER DIVISION
385 Madison Avenue, New York 17, N. Y.

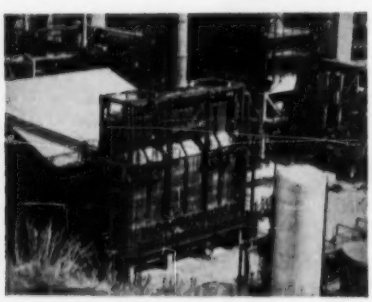


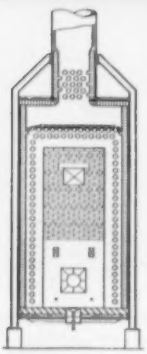
Lummus Standard Oil Heaters are made in two basic types. The up-take heater, illustrated at the left, conducts the products of combustion upward from the entire heating chamber at low and uniform levels of velocity.





The down-take heater, illustrated at the left, is suitable for service where products of combustion would contain corrosive elements or solid matter. It draws hot gases downward from the combustion chamber through the diffusion baffles. Both types of Lummus Standard Heaters are adaptable for multi-coil or multi-stage heating.





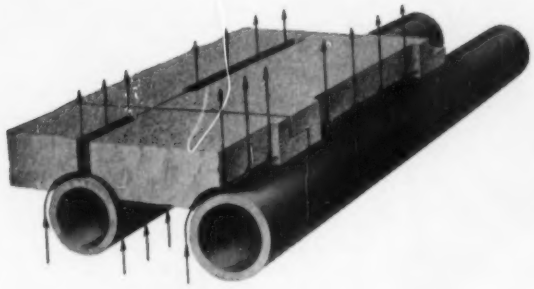
The Economy Heater, illustrated at the left, finds wide application in smaller refineries where the investment necessary for extensive maintenance platforms and roofing is not justified. The flexibility and variety of capacities available with multi-coil and multi-stage settings can be obtained with Lummus-Built Heaters in the same manner as with the larger Standard units.

Lummus Standard Oil Heaters and Lummus-Built Heaters are the answer to the vital problem of supplying process heat in any required amount for petroleum refineries, chemical and petro-chemical plants. Single Lummus Heaters are operating at continuous heat absorptions ranging from 100,000 to 300,000,000 BTU per hour. Lummus has designed and installed heaters for use with every major process.

**BRANCH OFFICES** — Houston: 2707 Weslayan Rd., Houston 6, Texas • England: The Lummus Co., Ltd., 80 Regent St., London W1, England • France: Societe Francaise des Techniques Lummus, 39 Rue Cambon, Paris 1er, France

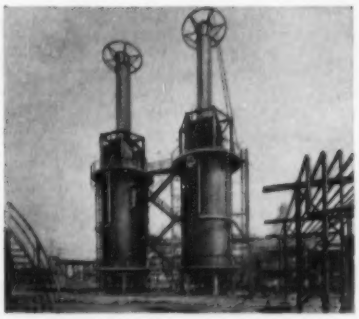
# LUMMUS

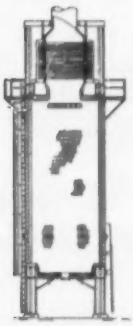
**OIL HEATER DIVISION**
385 Madison Avenue, New York 17, N. Y.



The patented gas diffusion baffle arrangement shown at the left is characteristic of Lummus furnaces. This arrangement creates a draft resistance or dampering effect which assures uniform evacuation of the products of combustion over the entire ceiling area of the combustion chamber.

Benefits obtained by the use of the slotted refractory baffle tile include high velocity gas flow over the shielded upper row of roof tubes—with consequent high convection heat pick-up—and re-radiated heat from the under side of the tile to the upper side of the bottom row of roof tubes.





Lummus-Built Heaters incorporate the same material, mechanical and operating advantages of the Lummus Standard Oil Heaters but are built along the more simplified and economical lines possible with their smaller size. The Lummus Vertical Tube Heater, illustrated at the left, for milder heat requirements, is especially designed for limited space installation.

The portable heater, left, was built for Magnolia in record time—a mere six weeks downtime compared with the usual five months. It is the height of flexibility and is a smooth-running 100,000,000 BTU per hour heater handling 36,000 B/D of charge stocks—an increase of several thousand barrels over the heater it replaced.

The heaters described above are, of course, Lummus designed. Lummus also has built and will build for you, if requested, counter-parts of all popular types of furnaces used in the petroleum, chemical and petro-chemical industries. Lummus can also build to your specifications any type of specialty heater that a particular production problem calls for. Lummus' 50 years of experience in constructing petroleum and chemical plants lies behind the work of the Oil Heater Division, providing the knowledge necessary to do any job requested by a customer—and to do it right.

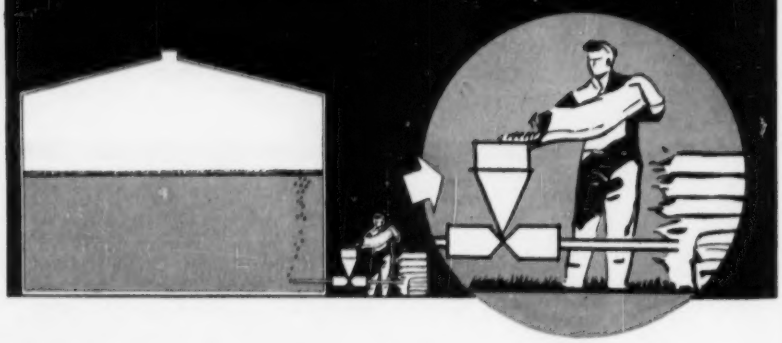
**BRANCH OFFICES** — Chicago: 600 South Michigan Ave., Chicago 5, Illinois • Venezuela: Compania Anonima Venezolana Lummus, Edificio "Las Grandillas", Esquina Las Gradillas, Caracas, Venezuela • Canada: 455 Craig St. West, Montreal


For more data on advertised products, use Readers' Service Cards, last page.

*at the frontiers of progress you'll find . . .*

AN AIR REDUCTION PRODUCT

**Here's the easiest "do-it-yourself" project you ever undertook . . .**



## Installing COLFOAM MICROBALLOON* Spheres for Big Savings in Cone-Roof Crude Oil Tankage

Installing a blanket of Colfoam Microballoon Spheres in cone-roof tanks is easy— so easy you can do it yourself. And the results of installing this Colfoam Microballoon Spheres blanket are dramatic. Evaporation losses are immediately cut by as much as 86%.

Colfoam Microballoons, exclusive with Colton Chemical Company, are microscopically-small, gas-filled spheres made of urea formaldehyde, which float on the surface of stored crude oil to form a foam-like seal. They soon pay for themselves in the amount of stored material they save.

Complete Colton technical service, *at no additional cost,* surveys your storage problems, estimates the quantity of Colfoam Microballoon Spheres needed, supervises initial installation. Helpful instruments are supplied—a Portable Gage Tape Well assists in accurate readings of the amount of crude stored and a Foam Sampler measures foam thickness.

Write today for full information, for facts-and-figures proof of substantial savings through efficient evaporation control.

*COLFOAM Reg. T. M. Colton Chemical Co. MICROBALLOON Reg. T. M. Standard Oil Co. (Ohio)

COLTON

**COLTON CHEMICAL COMPANY**

*A DIVISION OF AIR REDUCTION COMPANY, INC.*

**1747 Chester Avenue • Cleveland 14, Ohio**

**Sales Offices and Warehouse Facilities Throughout U. S.**

**Export: Airco Company International, New York 17, N. Y.**

**Products of other divisions of Air Reduction Company, Inc. include: AIRCO—industrial gases, welding and cutting equipment PURECO — carbon dioxide, liquid-solid ("DRY-ICE") OHIO — medical gases and hospital equipment NATIONAL CARBIDE — pipeline acetylene and calcium carbide.**

## Men in the Industry . . .

Chemical Engineers in 1951. He served as president of the Institute in 1954.

Dr. Thomas was born in Hendersonville, N. C., in 1905. He received both B.S. and M.S. degrees from the University of North Carolina, and a Ph.D. degree from Northwestern University. Dr. Thomas is known in the oil industry as the author of more than two two dozen articles and over 100 patents. His activity in numerous professional and technical societies includes membership in the American Chemical Society dating from 1927, and the Society of Automotive Engineers since 1939.

**Dr. W. L. Faith** has been appointed managing director of the Air Pollution Foundation.

Faith, 49, has served as chief engineer of the foundation since the organization began operations in 1954. He succeeds **Dr. Lauren B. Hitchcock,** who has resigned to return to private consulting practice in the industrial research and development field.

**A. G. Schei,** treasurer of Shell Oil Co., has been named vice president-finance effective January 1, 1957. Schei succeeds **J. H. White,** who will retire December 31 after 31 years of service.

Schei

**C. C. Combs,** vice president and treasurer of Shell Pipe Line Corp., Houston, will succeed Schei as treasurer. **A. F. Hagen,** Shell's treasury manager of the Houston exploration and production area, will succeed Combs as vice president and treasurer of the Pipe Line Corp.

Schei joined Shell in 1924 as a clerk in the treasury department at Seattle, Wash. He has held positions in the financial organization at Seattle, San Francisco and New York. He was appointed treasurer of Shell Chemical Corp., in 1948 and treasurer of Shell Oil Co., in 1949.

White joined Shell in 1925 as a clerk in the treasury department of the Los Angeles marketing division. In 1944, he was elected vice president-treasurer of the West Coast division, and in 1949, he went to New York as vice president and controller. He was elected vice president-finance in 1954.

Combs started with Shell in 1923 as a service station attendant in California. He became assistant treasurer and assistant controller of Shell in the San Francisco office in 1949. In 1955 he was elected vice president of Shell Pipe Line Corp.

Mr. Hagen, with Shell for 32 years, has held responsible positions in Shell's financial organization on the West Coast and in Houston.

**J. L. Miller,** superintendent-operations of Shell Oil Co.'s Houston refinery, has been named manager of the Montreal refinery of Shell Oil Co., of Canada, Ltd. The promotion and transfer will be effective January 1. His successor at Houston will be announced shortly, the company said.

A veteran of 36 years with Shell, Miller started with the company as a gager at Wood River, Ill., in 1920. He became as-

—Photograph courtesy of Standard Oil Co. of N. J.

# with Ljungstrom® Air Preheaters, four of your present stills can do the work of five

You'll have far less slag—much less downtime for maintenance—with the Ljungstrom Air Preheater. This unit produces more complete combustion, at higher temperatures, because preheated air mixes more thoroughly with fuel. And in addition, Ljungstrom efficiency makes possible finer process control and advanced furnace designs. Thus, Ljungstrom savings are real and measurable. One still, Ljungstrom equipped, added $58,000 of income annually from higher product quality alone.

### How fast is "WRITE OFF"?

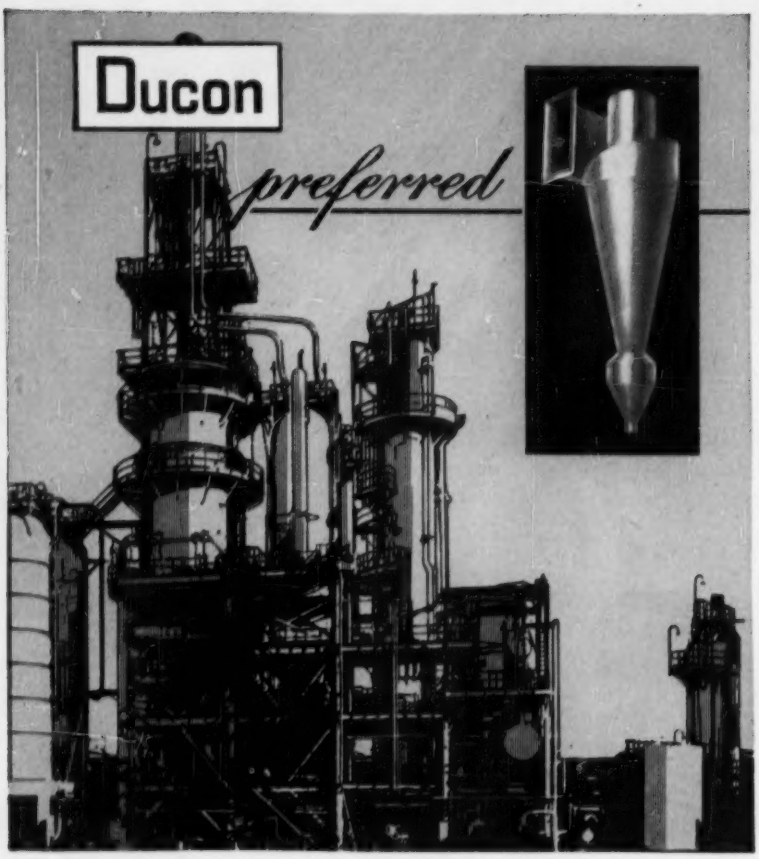
Unusually short. Major savings are gained from higher average octane ratings. And other Ljungstrom advantages —up to 20% fuel savings . . . more economical furnace design, with no need for convection surfaces . . . use of many fuels you used to throw away . . . consistently higher throughput . . . shorter turnaround time—mean that a Ljungstrom is paid out in a very few months.

For more complete details on what the Ljungstrom Air Preheater can do for you . . . for an analysis of the heat recovery benefits attainable in fuel burning equipment—call or write the Air Preheater Corporation.

***Wherever You Burn Fuel, You Need Ljungstrom***

The Ljungstrom operates on the continuous regenerative counterflow principle. The heat transfer surfaces in the rotor act as heat accumulators. As the rotor revolves, the heat is transferred from the waste gases to the incoming cold air.

**The Air Preheater Corporation** 60 East 42nd Street, New York 17, N. Y.




**. . . for Catalyst Recovery in Leading Oil Refineries throughout the World**

**Ducon Type SDC Cyclones are specifically designed for high efficiency operation in petroleum refining processes such as:**

- **Fluid Bed Catalytic Cracking**
- **Thermofor Catalytic Cracking**
- **Elutriator Towers**
- **Fluid Coking**
- **Fluid Hydroforming**
- **Catalyst Disposal and Conveying**
- **All Fluid Solid Operations**

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275 James Street North, HAMILTON, ONTARIO

THE **Ducon** COMPANY

147 EAST SECOND STREET, MINEOLA, N.Y. • Sales Representatives in Principal Cities

*Designers and Manufacturers of Dust Control Equipment Exclusively*

**CYCLONES • CENTRIFUGAL WASH COLLECTORS • TUBULAR CLOTH FILTERS • DUST VALVES**


## Men in the Industry . . .

sistant manager of the cracking department at Shell's Arkansas City, Kansas, refinery in 1923. He was made assistant superintendent of the East Chicago refinery in 1928, and became superintendent of the same plant in 1935.

He was transferred to Houston in 1937 as superintendent, and has held that post until his present promotion.

**Dr. Everett C. Hughes,** manager of research in the manufacturing department of The Standard Oil Co., (Ohio) was presented a citation of merit at the eighth annual dinner of the Chemical Profession in Cleveland.

This citation was "in recognition of Dr. Hughes' outstanding contributions to the enhancement and interpretation of the chemical profession in the Cleveland area."

**P. M. K. Embling and D. R. Brown** have been appointed by the Power-Gas Corp., Ltd., Stockton-on-Tees, as divisional directors who will be responsible for the development of the company's trade within special fields.

P. M. K. Embling was appointed manager of the chemical plant division in 1955 and now becomes divisional director responsible for that division. He was educated at King's School, Worcester, and while training in various departments of Ashmore, Benson, Pease & Co., and The Power-Gas Corporation Ltd., took an Honors degree in engineering as an external student of London University.

D. R. Brown was appointed manager of the blast furnace division of Ashmore, Benson, Pease & Co., in 1955 and as divisional director he is now responsible for the promotion and development of blast furnace and ancilliary plant marketed by the company. Brown, after leaving school, obtained his first practical engineering experience in the shops of Ashmore, Benson, Pease & Co., and on erection of blast furnaces. At Cambridge, he obtained a B.A. degree in engineering.

**Jake L. Hamon,** Dallas, **and Frank M. Porter,** Oklahoma City, were re-elected chairman of the board and president of the American Petroleum Institute, respectively, at the association's 36th Annual Meeting in the Conrad Hilton hotel.

Four new vice presidents and 17 new directors were also elected.

The new vice presidents are:

Production: **D. L. Connelly,** Houston, senior vice president and a director of Warren Petroleum Corp.;

Marketing: **Dwight T. Colley,** Philadelphia, vice president and general manager of marketing, Atlantic Refining Co.;

Refining: **H. W. Ferguson,** Houston, vice president of Humble Oil and Refining Co.;

Transportation: **Frank O. Prior,** Chicago, president of Standard Oil Co. (Indiana);

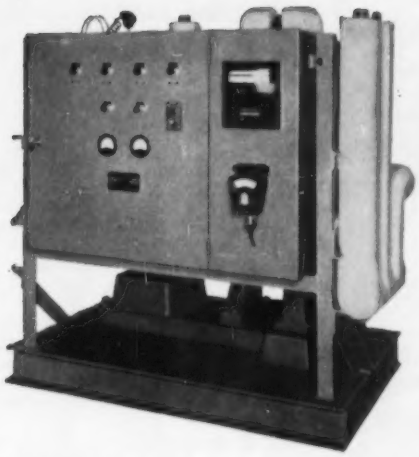
Elected as treasurer was **B. B. Jennings,** New York, board chairman of Socony Mobil Oil Co., Inc.

The A.P.I. reelected **Lacy Walker** as secretary. Since Walker is retiring on March 1, the Institute named **R. H. Stewart,** of the A.P.I. staff, assistant secretary.

In addition to the 17 new directors, **T. H. Barton,** El Dorado, Ark., founder and chairman of Lion Oil Co., now a division of Monsanto Chemical Co., was

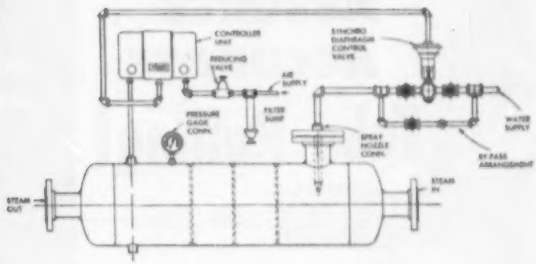


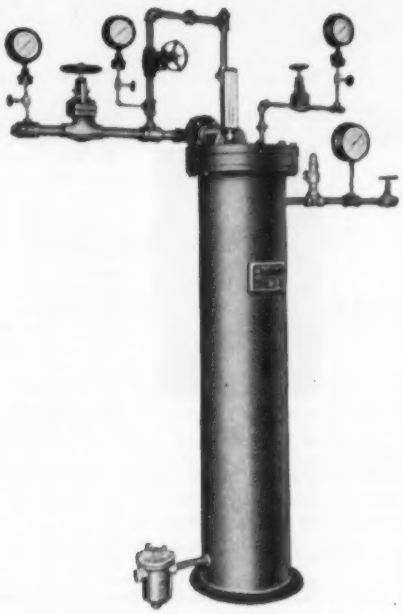
For more data on advertised products, use Readers' Service Cards, last page.



**TRANSFER OIL HEATING SYSTEM** Includes standard heat exchangers and vessels with complete operating controls to maintain oil supply temperature within ±2°F.

**DESUPERHEATING SYSTEM** "Washes out" steam superheat through evaporation of a controlled amount of feed water. Four standard size systems handle wide range of steam loads (8,000 to 150,000 lb./hr.)



**CHLORINE VAPORIZING SYSTEM** Converts liquid chlorine to dry vapor. Capacities to 8,000 lb./hr. of chlorine with steam at 5 p.s.i.g. All-steel construction, easily disassembled and cleaned.

# COMPLETE "PACKAGE" PROCESS SYSTEMS

Whitlock "Package" Service fulfills every need in procuring your equipment. It covers all engineering, with recommendations based on your actual flow sheets specifying fluids, temperatures, and pressures, which we translate into terms of mechanical equipment. We furnish all component units, including exchangers, tanks, pressure vessels, towers, reactors, condensers, columns, reboilers, coils, piping, and operating controls. We relieve you of the considerable expense and annoyance of purchasing and expediting many supplies from many sources. Our stocks of materials . . . plate, pipe, heads, tubing, forgings and other basic materials for quick fabrication . . . are available in ample supply to permit us to make prompt shipment of your equipment.

This "Package" Service when used to produce units such as the Transfer Oil Heating System, Chlorine Vaporizing System, and Desuperheating System illustrated, can obviously save you time and money. It pays to deal with a single manufacturer — a competent producer of engineered equipment. Write

**The Whitlock Manufacturing Company**
**75 South Street, West Hartford 10, Conn.**

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# Whitlock

**Designers and builders of bends, coils, condensers, coolers, heat exchangers, heaters, piping, pressure vessels, receivers, reboilers.**



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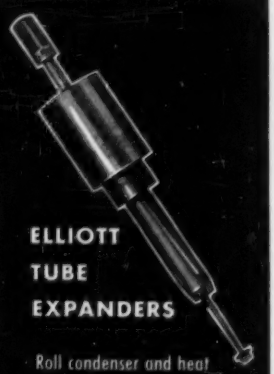
ELLIOTT EQUIPMENT ASSURES ACCURATE Tube Rolling!

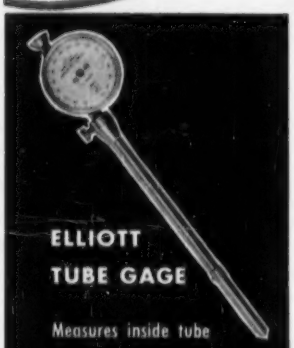


ELLIOTT TUBE EXPANDERS

Roll condenser and heat exchanger tubes quickly and accurately. Rotating, parallel self-feeding rolls insure good joints. For tubes ½ in. through 1½ in.

Table for data on torque control setting
Time delay adjustment
Torque Control setting
Red light indicates power on
White light indicates tube is rolled
Motor cord
Power cord
Operating instructions
Voltage Balance indicator dial
Voltage Balance switch
Power switch
Motor selector switch
Remote signal light with 25-ft cord indicates when tube is rolled

The control box is equipped with heavy non-skid rubber feet. These also protect it against water on the floor, etc



ELLIOTT TUBE GAGE

Measures inside tube diameters on dial in thousandths of an inch. A quick guide for setting tube expanders for condenser and heat exchanger tubes. Three-point contact of hardened steel balls insures accurate measurements.

ELLIOTT ELECTRIC CONTROL

Assures tight, uniform tube joints everytime. It's a torque-limiting device that automatically balances outside voltage variables without the need of a separate voltage regulator.

Write for Descriptive Bulletin Y-40. Elliott Company, Lagonda Division, Springfield, Ohio.

ELLIOTT Company

Y6-2A

STEAM TURBINES • MOTORS • GENERATORS • DEAERATING HEATERS • EJECTORS • CONDENSERS • CENTRIFUGAL COMPRESSORS • TURBOCHARGERS • TUBE CLEANERS • STRAINERS


## Men in the Industry . . .

elected an honorary member of the board.

The new directors are:

**C. W. Barrett,** The Texas Co., Houston; **D. L. Connelly,** Warren Petroleum Corp., Houston; **Harry W. Ferguson,** Humble Oil & Refining Co., Houston; **Max Fisher,** Aurora Gasoline Co., Detroit; **J. W. Foley,** The Texas Co., New York.

**Harry J. Kennedy,** Continental Oil Co., Houston; **R. L. Kidd,** Cities Service Oil Co., Bartlesville; **J. F. Lynch,** La Gloria Oil & Gas Co., Corpus Christi; **C. H. Murphy, Jr.,** Murphy Corp., El Dorado, Ark.

**Fred F. Murray,** Oil Well Supply Co., Dallas; **A. L. Nickerson,** Socony Mobil Oil Co., Inc., New York; **Ed Parkes,** United Gas Pipe Line Co., Shreveport; **A. C. Rubel,** Union Oil Co. of California, Los Angeles.

**E. L. Steiniger,** Sinclair Oil Corp., New York; **L. A. Sunkel,** Atlantic Refining Co., Dallas; **W. M. Vaughey,** Vaughey & Vaughey, Jackson, Miss.; and **R. Wagner,** Chicago Corp., Chicago.

Several top officers of the Institute were reelected. They are **Jake L. Hamon,** Dallas, chairman of the board; **Frank Porter,** Oklahoma City, president; **F. O. Prior,** Standard Oil Co. (Ind.), Chicago, vice president for transportation; and **B. Brewster Jennings,** Socony Mobil Oil Co., Inc., New York, treasurer.

**Dr. J. Bennett Hill,** pioneer oil industry chemist, has retired as director of Sun Oil Co.'s research and development department.

Hill

Dr. Hill has helped manage Sun's research program for the past 22 years. He joined the company in 1934 as manager of the development division, manufacturing department. He directed oil research for the Atlantic Refining Co., for 11 years prior to joining Sun.

Dr. Hill, who was born in Philadelphia, is a graduate of Friends Select School. He was awarded his B.S. and Ph.D. degrees in chemistry from the University of Pennsylvania in 1913 and 1916, respectively.

In 1950, the American Petroleum Institute presented to him a Certificate of Appreciation honoring his contributions to the API's research program. It was the first such award presented by the Institute in recognition of research activities.

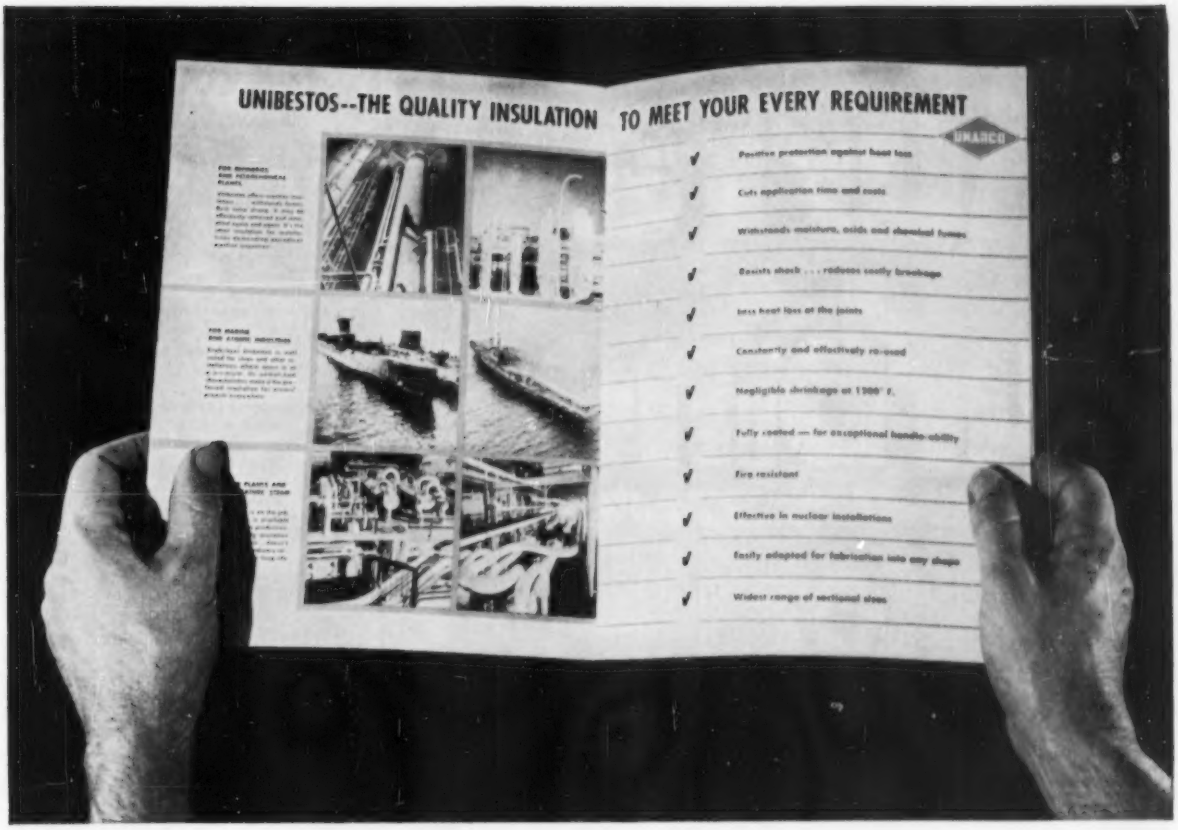
**I. W. Scroggin,** New York, has been appointed assistant plant manager in charge of technical services for the Cities Service refinery at east Chicago, Ind.

Scroggin will take over his new duties at the East Chicago plant on Jan. 1. He was first employed by Cities Service in 1946 and served as process engineer at the Cities Service Refining Corp., refinery at Lake Charles, La., until 1951. At that time, he was transferred to the manufacturing department of Cities Service Petroleum, Inc., in New York City. He is serving there as staff engineer.

**Dr. Edward W. Comings,** head of the school of chemical and metallurgical



For more data on advertised products, use Readers' Service Cards, last page.




# A NEW BOOK...and a new way to select pipe insulation for greatest savings

Now there's a fast, easy way to select economic thickness of pipe insulation accurately...efficiently. It's featured in the new Unibestos Catalog. This handy guidebook introduces a new simplified method based on a special "J" factor. The easy-to-use "J" index eliminates most of the complicated, time-consuming computation required by other methods.

Selecting Unibestos is a smart move, too. Made of Amosite asbestos, Unibestos® protects against heat loss with only *single-layer application.* Strong interlacing fibers seal in more heat at the difficult joints than any other single- or double-layer insulation.

Built strong to stay strong, yet easy to miter and cut, Unibestos goes on the most difficult fittings easily... reduces application costs wherever it's used. Available in sectional form through 44" O.D.

**Write today for your copy of the new 40-page UNIBESTOS CATALOG**

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Please send me the new Unibestos Catalog.

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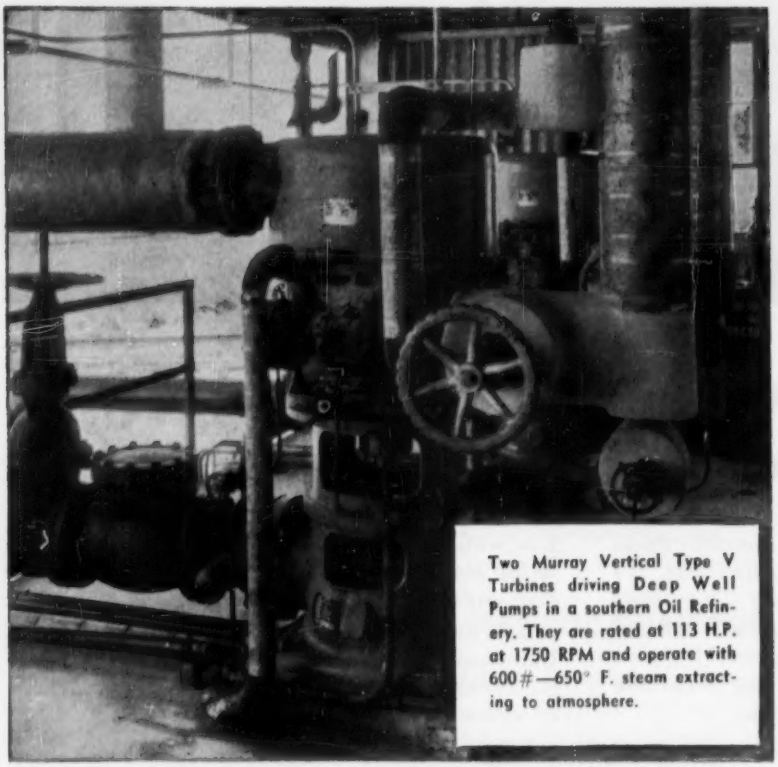
# Murray Turbines



Two Murray Vertical Type V Turbines driving Deep Well Pumps in a southern Oil Refinery. They are rated at 113 H.P. at 1750 RPM and operate with 600#—650° F. steam extracting to atmosphere.

• Murray Vertical V turbines, both geared and direct-connected, are being used more and more for driving vertical pumps of all types. The Murray Vertical V turbine is designed from top to bottom as a vertical turbine, not just a horizontal turbine, "upended." The Murray Vertical is especially constructed and arranged for vertical mounting.

Murray vertical turbines can be furnished for steam pressures up to 600#, 750° F. TT. and back pressures as high as 100# and can carry most normal thrust loads imposed by vertical pumps.

**MURRAY IRON WORKS COMPANY**

**BURLINGTON, IOWA**

*Builders of Steam Power Equipment for Three Quarters of a Century*


## Men in the Industry . . .

engineering, Purdue University, Lafayette, Ind., has received the William H. Walker Award for 1956 by the American Institute of Chemical Engineers. The award was to have been presented during the 49th Annual Meeting of AIChE at Boston Dec. 11.

Dr. Comings is the 21st winner of the award which was instituted in 1936 to encourage excellence in contributions to the chemical engineering literature.

Dr. Comings has published numerous articles on high pressure measurements, liquid-liquid extraction, drying and fluid flow and is the author of several books on chemical engineering. Born in Phillipsburg he received his B.S. degree in chemical engineering from the University of Illinois and his Ph.D. also in chemical engineering from the Massachusetts Institute of Technology.

**James G. Couch** has been named manager of the production department's engineering section for U. S. Industrial Chemicals Co., Division of National Distillers Products Corp.

Couch

A mechanical engineer with a degree from the University of West Virginia, Couch has been with U.S.I. and "Petro" since 1953. Previously he was employed by E. I. duPont de Nemours at the Belle, W. V., and Orange, Texas, Plants. During the Second World War, he was an officer in the U. S. Army Corps of Engineers and was stationed in Italy and the Philippines. Couch is an active member of the American Society of Mechanical Engineers.

**J. C. Ducommun** presented the report of the nominating committee at the open meeting of the division of Refining during the 36th annual meeting of the American Petroleum Institute. Thereupon the members elected the following to serve on the general committee of the division of Refining for the year 1957:

L. G. Alexander, International Refineries, Inc., Wrenshall, Minn.; Robert O. Anderson, Malco Asphalt and Refining Co., Roswell, N. M.; Earl Baldridge, Champlin Refining Co., Enid, Okla.; D. L. Campbell, The British American Oil Co. Ltd., Toronto; W. J. Carthaus, Great Northern Oil Co., St. Paul, Minn.; V. B. Chance, Atlas Processing Co., Shreveport, La.; R. M. Chesney, Deep Rock Oil Co., Oklahoma City; Miles F. Cowden, Consumers' Cooperative Assn., Wichita, Kans.; G. Davidson, Shell Oil Co. of Canada, Ltd., Toronto; G. A. Davidson, Standard Oil Co. of California, San Francisco; David E. Day, Richfield Oil Corp., Los Angeles; G. S. Dunham, Socony Mobil Oil Co., Inc., New York, and J. H. Dunn, The Shamrock Oil and Gas Corp., Amarillo, Texas.

Also, E. E. Ebner, Quaker State Oil Refining Corp., Emlenton, Pa.; A. G. Farquharson, McColl-Frontenac Oil Co. Ltd., Montreal; A. P. Frame, Cities Service Co., New York; P. N. Gammelgard, The Pure Oil Co., Chicago; C. O. Garbrecht, Bay Petroleum Corp., Denver; A. V. Hoffman, South Penn Oil Co., Pennzoil Div., Oil City, Pa.; Sam I. Hulse, Warren Petroleum Corp., Tulsa; H. Y. Hyde, Tidewater Oil Co., San Francisco; P. A. Kahle, The Frontier Refining Co., Cheyenne, Wyo.; T. B. Kimball, Sinclair Refining Co., New York; L. E. Kincannon, Rock Island Refining Corp., Indianapolis, and K. E. Kingman, Union Oil Co. of California, Los Angeles.

Also, Harry A. Logan, Jr., United Refining Co., Warren, Pa.; M. P. L. Love, Shell Oil Co., New York; R. E. Luton, The Ohio Oil Co., Findlay, Ohio; E. E. Lyder, U. S. Oil and Refining Co., Los Angeles; George L. Macpherson, Imperial Oil Ltd., Toronto; F. L. Martin, Sun-



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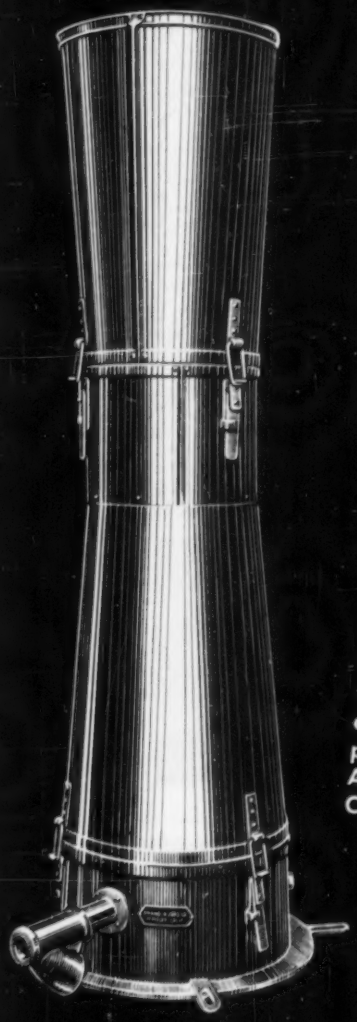

To meet the persistent demand for an EDUCTOR which would be applicable to the smaller bulk storage and lease tanks, marketing terminal and small refinery tanks and towers which need ventilating, we are now offering a 12" EDUCTOR designed to fit tank roof openings of 10 to 16 inches without modification. It will also fit smaller or larger ventilating openings by simple field adaption.

This model, ST-10500, is specifically designed for those applications where ventilation is mandatory, but where an air compressor of large capacity is not available. This model operates with a small air compressor which may be on hand or easily rented locally. This EDUCTOR is made of heavy gage galvanized iron, and comes complete with three simple, easily interchangeable bronze nozzles for 25, 35, and 50 cfm of prime mover air at 100 psi, as well as a pressure gage, and air strainer.

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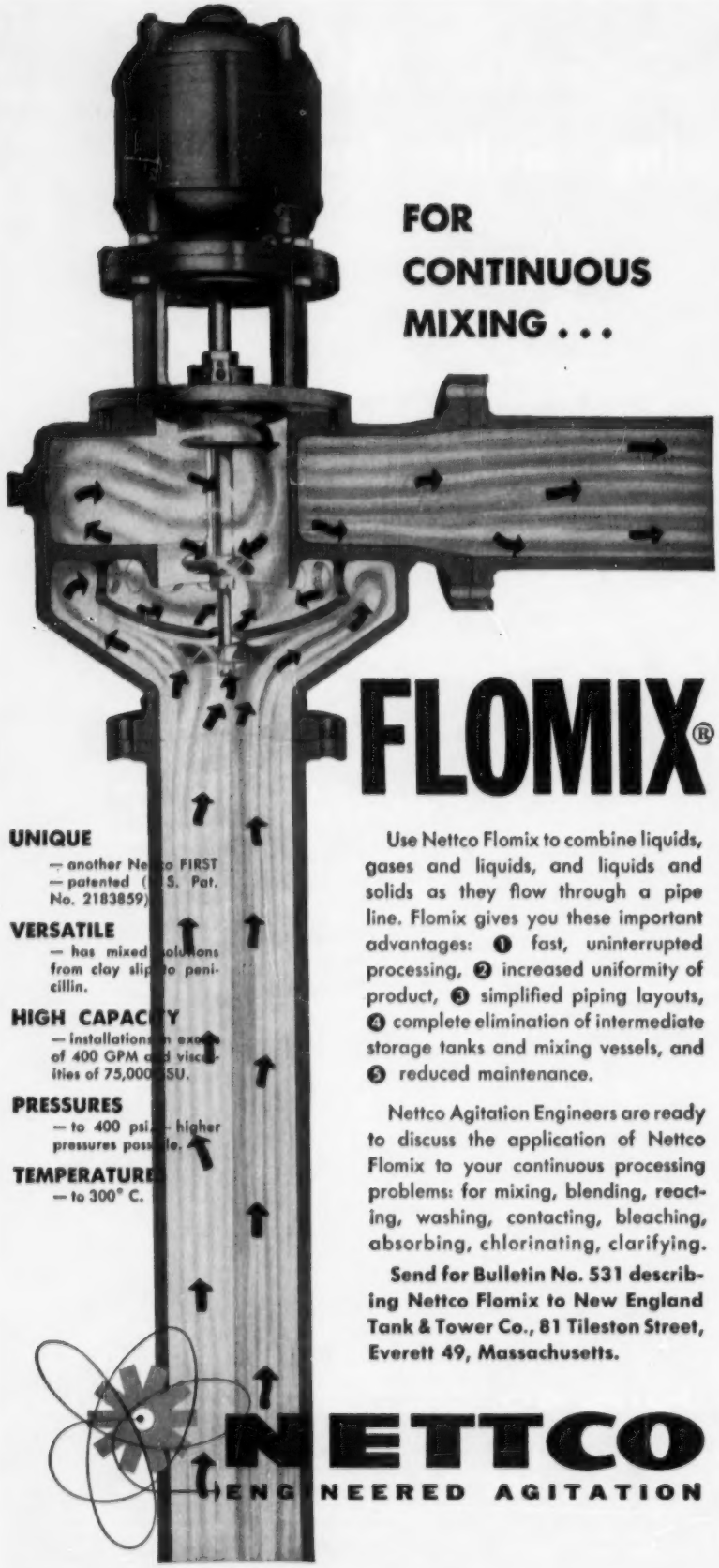

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Also William Naden, Esso Standard Oil Co., New York; J. W. Newton, Magnolia Petroleum Co., Beaumont, Texas; H. G. Osborn, Continental Oil Co., Ponca City, Okla.; H. M. Paulsen, Bankline Oil Co., Los Angeles; George J. Peterschmidt, The El Dorado Refining Co., El Dorado, Kans.; J. S. Pfarr, Leonard Refineries, Inc., Alma, Mich.; L. W. Robbie, Republic Oil Refining Co., Texas City; Roland V. Rodman, Anderson-Prichard Oil Corp., Oklahoma City, and J. B. Rogerson, Lion Oil Co., El Dorado, Ark.

Also, A. W. Scott, Wolf's Head Oil Refining Co., Oil City, Pa.; J. L. Sewell, Delhi-Taylor Oil Corp., Dallas; K. W. Shimeall, Crown Central Petroleum Corp., Houston; T. P. Simpson, General Petroleum Corp., Los Angeles; H. V. Smith, Kendall Refining Co., Bradford, Pa.; Henry Sonneborn, III, L. Sonneborn Sons, Inc., New York; J. S. Stackner, Clark Oil and Refining Co., Blue Island, Ill.; Irving J. Staid, Carter Oil Co., Billings, Mont.; W. F. Stroud, The Atlantic Refining Co., Philadelphia, and T. J. Sullivan, Gulf Oil Corp., Pittsburgh.

Also, C. C. Tate, Phillips Petroleum Co., Bartlesville, Okla.; C. H. Thayer, Sun Oil Co., Philadelphia; Clay Thompson, Mohawk Petroleum Corp., Bakersfield, Calif.; R. L. Tollett, Cosden Petroleum Corp., Big Spring, Texas; B. B. Turner, Ethyl Corp., New York; J. W. Vaiden, Skelly Oil Co., Tulsa; Russell H. Venn, Humble Oil and Refining Co., Houston; J. S. Wertz, The Vickers Petroleum Co., Inc., Wichita, Kans.; Kenneth A. West, Canadian Oil Cos., Ltd., Toronto; John S. Worden, The Texas Co., New York; G. E. Wynn, D-X Sunray Oil Co., West Tulsa; Robert E. Yancey, Ashland Oil and Refining Co., Ashland, Ky.

**Marshall Sittig,** formerly of Ethyl Corporation, and frequent contributor to PETROLEUM REFINER has been elected managing director and president of the American Lithium Institute. Sittig is widely known for his many technical writings in the petroleum field. He is an authority on the alkali metals.

Sittig

Other officers of the Institute are: vice presidents, **J. D. Campbell,** Lithium Corp., **A. J. Dirksen,** American Potash; and **J. Fentress,** Foote Mineral.

The board of directors will also be comprised of **L. G. Blis,** Foote Mineral; **Peter Colefax,** American Potash; and **H. W. Rogers,** Lithium Corp.

The secretary-treasurer of the Institute is **M. F. McCarthy,** of Oliver and Donnally.

**Dr. Fred M. Jacobsen, Jr.,** has been promoted to group leader of the computer programming and mathematical analysis group in the research and development department of the American Oil Co., Texas City.

Dr. Jacobsen was employed by the company in 1955, and since then has been in the process development section of the department. He received a B.S. degree in chemical engineering from Brooklyn Polytechnic Institute, and obtained a Ph.D. in chemical engineering at Iowa State College in 1954.

**C. M. Gile,** vice president, Gulf Oil Corp. has retired after 30 years service.

Educated at Phillips Academy, Andover, Mass., and Yale University, Gile first entered the oil business with the New Eng-

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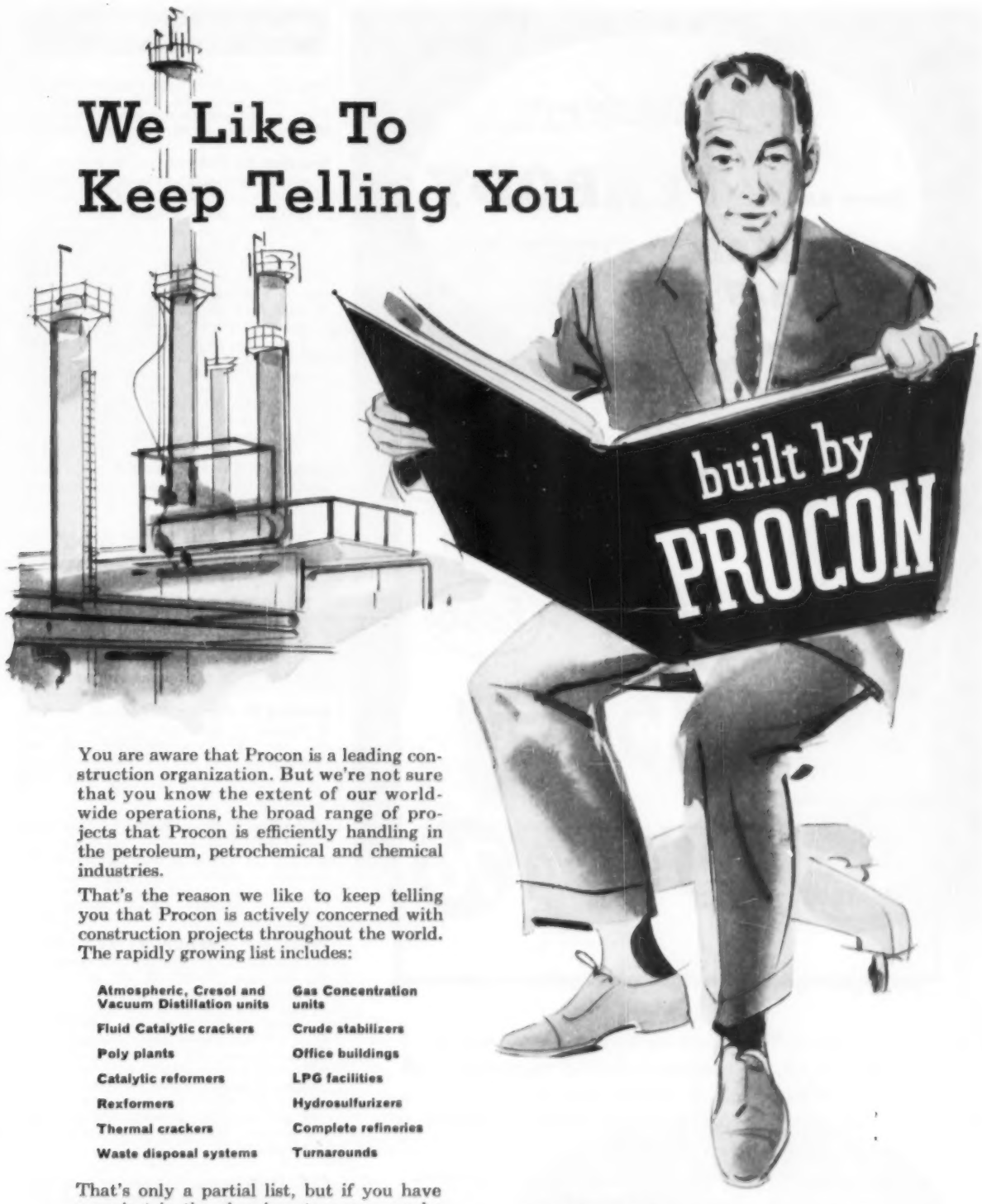


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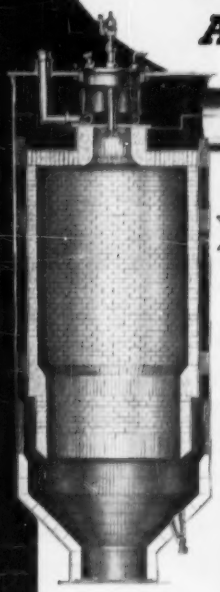

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## Men in the Industry...

land Oil Co., Boston, as sales manager in 1920. He joined the Gulf companies in 1926 as assistant to the general manager of sales in the general office in Pittsburgh.

**Gordon B. Thayer** has been promoted to plastics specialist on the staff of plastics technical service, The Dow Chemical Co.

In his 15 years with Dow, Thayer spent six years with the saran development laboratory and the past nine years as head of the molding section of plastics technical service. This work, along with his activities in various technical societies has brought him international recognition as an authority in the plastics molding field.

A graduate of the University of Michigan with a B.S.E. degree in mechanical engineering in 1934, Thayer came to Dow after several years' experience in design of special machinery and plastic molding work. He is the author of more than 30 papers in the plastics field.

**James O'Conner Brown,** plant manager, Petro-Tex Chemical Corp., Houston, since 1955 has been elected a vice president of that company.

Brown first joined Sinclair Refining Co. as assistant superintendent of the Meraux plant. In 1922, he came to the Houston refinery as lube oil supervisor. During World War II he was selected to assume responsibility for a Sinclair-operated government butadiene plant built close to the Houston refinery. Sinclair Rubber Corp. operated this plant for the government until 1955, when it was sold to Petro-Tex.

**Robert S. Custer** has joined the firm of Ehrhart & Associates, Inc., Los Angeles and San Francisco, engineers and constructors, as chief process engineer. Custer will be located at the company's head office in Los Angeles.

**Nicholas J. Campbell, Jr.,** has been named associate general counsel of Standard Oil Co. (New Jersey) in New York. Recently Campbell joined Jersey Standard after having served Creole Petroleum Corp. as a director and vice president.

**Professor Arthur V. Tobolsky** of Princeton University has been presented the Bingham Medal of the Society of Rheology. **Dr. John H. Dillon** of Textile Research Institute made the presentation. Professor Tobolsky's research efforts in the fields of the elastoviscous properties of polymeric materials and the kinetics of polymerization reactions were reviewed. In his acceptance speech Professor Tobolsky, instead of lecturing on technical matters, discussed the personal problems encountered by a scientist in his professional career.

**F. C. Cutting** became assistant to the vice president of Shell Oil Company, New York, for personnel and industrial relations. Formerly he was in charge of economic development. **J. E. Marsland** was named assistant to the executive vice president and will conduct special economic studies coordinating work of several departments of Shell companies. **J. M. Brackenbury** will succeed Marsland as manager of the manufacturing technological department. Brackenbury was formerly superintendent of the Martinez, California, refinery. This post is



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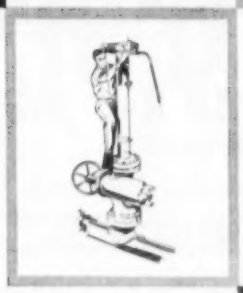

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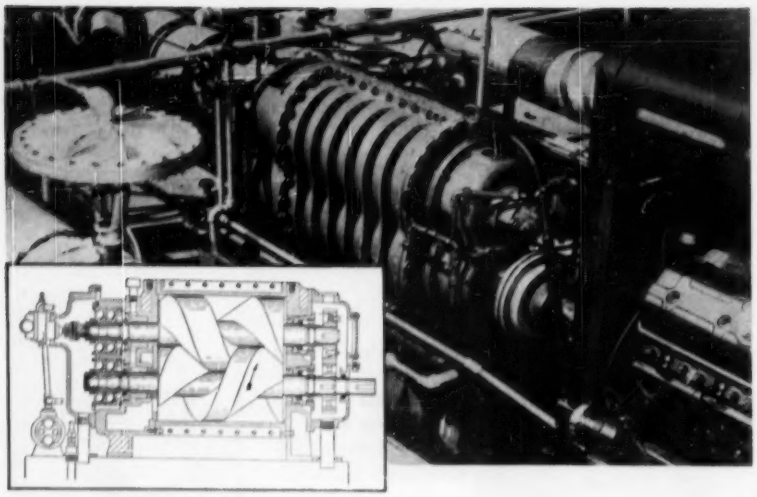

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## Men in the Industry . . .

being filled by **J. B. Dunlap. J. B. St. Clair,** former assistant manager of the head office manufacturing technological department, will replace Dunlap.

**Chalmer G. Kirkbride** has joined Sun Oil Co. as executive director of the Research, Patent and Engineering departments.

In accepting the new position at Sun, Kirkbride resigns as president and chairman of the board of directors of Houdry Process Corp., Philadelphia.

**James R. Anslow** has joined Escambia Chemical Corp. as a technologist in the Technical department at Pensacola. Anslow graduated from Texas Technological College with a chemical engineering degree in 1949. Since that time he has been employed by Magnolia Petroleum Co., Dallas, and Monsanto Chemical Co., Texas City.

**Foster Dee Snell,** president, Foster D. Snell, Inc., New York City, has been elected vice president of the Association of Consulting Chemists and Chemical Engineers, Inc. Snell is a frequent contributor to PETROLEUM REFINER and has an article appearing on Page 139 this issue.

### Deaths

**Harry F. Sinclair,** retired founder of Sinclair Oil Corp., died November 10, in Pasadena, Calif. He was born July 6, 1876, at Wheeling, W. V., and grew up in Independence, Kan. In 1898, he graduated from the University of Kansas, and returned to Independence to become a pharmacist. Three years later, he became a partner in an oil drilling venture, and in another eight years he was a millionaire. He formed companies from time to time which were eventually consolidated into Sinclair Oil Corp., in 1943. In 1949 after more than half a century in the petroleum business, Sinclair retired as president of the organization, and in 1954 he stepped down from the board. He was 80 at the time of his death.

**Frederic A. Loeffler,** director of labor relations for ALCO Products, Inc., died in Ellis Hospital after a short illness. Loeffler joined ALCO Products, Inc., in May, 1942, as an assistant in the plant manager's office at Schenectady. He was named director of labor relations in 1951.

**Julio G. Bejarano,** 54, manager of Shell Chemical Corporation's Denver plant, died October 24 in a Denver hospital after a brief illness. Educated at the University of Chile and the University of California, where he obtained a B.S. degree in mechanical and hydro electric engineering, Bejarano joined Shell in 1926. In 1952, when the company purchased the Julius Hyman Company, Bejarano moved to Denver to manage the local plant.

**James Kniveton,** vice president-engineering, Selas Corporation of America, Dresher, Pa., died November 12 after a short illness. Associated with Selas since 1935, Kniveton was responsible for many heat processing developments in the metal, ceramic, glass and other industries, and a number of patents have been issued in his name.

Published by THE GULF PUBLISHING COMPANY, Box 2608, Houston, Texas

# 1956 ANNUAL INDEX

**VOLUME 35**

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# AUTHOR INDEX
## PETROLEUM REFINER

### VOLUME 35—1956


**A**

AKERS, W. W., AND BURNS, J. D.
Compressibility Factor of Mixtures....March 154
AKERS, W. W., AND MCALLEN, R. A. Pick Off Viscosity....March 153
AKERS, W. W., AND RALPH, H. T. Find Specific Heat Fast..March 151
AKERS, W. W., AND SAMPSON, O. A.
Shorten Heat Transfer Problems....March 152
ARIES, ROBERT S. Licensing Your Process....Feb. 147
ARIES, R. S., AND SACHS, A. P.
Lube Oil Additives—A Big Business....May 235
ARNOLD, M. L., AND HULL, R. J. Revamping a Gasoline Plant..April 148
AUSTIN, N. A. Designing an Electric Power System....March 201

**B**

BACKENSTO, E. B., DREW, R. D., AND STAPLEFORD, C. C.
What Happens in $H_2S$ Corrosion....Jan. 147
BACKENSTO, E. B., DREW, R. D., AND VLACHOS, J. N.
Hydrogen Sulfide Corrosion in Sovaformers....Aug. 165
BALE, E. S., MANT, E. L., AND WEBTER, R. E.
How to Measure Maintenance Results....May 159
BARRY, CHARLES B. *See* KITTERMAN, LAYTON
BEAUGH, J. B. *See* THOMAS, B. W.
BEDFORD, JACK E. How to Handle Employe Grievances....May 285
BELDEN, D. H. Penex and Platforming Team Up....Oct. 149
BOTHLER, HOWARD M. Performance Characteristics of
Reciprocating Compressors....Nov. 129
BOTT, L. L. *See* MING, E. T.
BRANDON, A., AND ZAHNSTECHER, L. W.
Refinery Integrates Three Hydrofiners....Oct. 166
BRAS, G. H. P. Simplify Gas Cooling Design....March 191
Design of Cooler Condensers....June 177
Design Direct Contact Coolers Quickly....Dec. 215
BRENNER, NATHANIEL. *See* COATES, VINCENT J.
BRIGHT, WILLIAM E., JR. A Place to Grow....May 268
BROOKE, MAXEY. Computing Cooling Tower Performance....March 182
Simplify Boiler Water Treatment....May 193
BROSAMER, R. J., AND GOTH, P. E., JR.
This Plant Is Going Modern....April 152
BROWN, ARTHUR A. Refining Can Use Operations Research...Feb. 102
BUCKLIN, R. W. Check This Plant's Pumping System....April 155
BURHANS, RALPH W., AND JACKSON, WARREN, JR.
Mass Spectrometer Monitoring....March 179
BURNS, J. D. *See* AKERS, W. W.
BUTLER, R. E., AND COLEMAN, R. P.
Exchanger Preventive Maintenance Pays....Jan. 111

**C**

CABLE, JACK A. How to Select Centrifugal Pumps....Sept. 241
CALLAHAN, R. W. Improved Human Relations....Jan. 235
CANJAR, LAWRENCE N.
There's a Limit to Use of Equations of State....Feb. 113
CARMINE, C. C. Preventive Maintenance in Action....May 154
CAUTHEN, WILLIAM C. New Refinery Trades Coke for Power..Aug. 141
CHANDLER, DR. ROBERT E.
Need Craft Apprentices? Try Personnel Tests....Dec. 266
CLARKE, LOYAL. *See* WINSTON, R. E.
CLEMENS, HOWARD P., AND CLOUGH, CHARLES.
Check Effluent With Bioassay....June 197
CLEVELAND, A. E. Fuel Injection Changes Emphasis....July 145
CLOUGH, CHARLES. *See* CLEMENS, HOWARD
COATES, VINCENT J., AND BRENNER, NATHANIEL.
Fuel Gas Analysis by Chromatography?....Nov. 197
COLEMAN, R. P. *See* BUTLER, R. E.
CONETTA, M. A. *See* NEWTON, E. C.
COOPEY, WALTER. Holding High-Pressure Joints....May 189
CORMACK, L. J. Maintenance Needs Engineers....Jan. 120
COTTINGHAM, P. L. *See* CRECELIUS, R. L.
COX, JOHN T., JR., AND WEINRICH, W. WHITNEY.
Look at Synthetic Rubber Raw Materials....Dec. 138
CRAWFORD, HORACE R. Take Another Look at Charcoal Test..April 166
CRAWFORD, P. B., AND CUNNINGHAM, W. A.
Carbon Formation in Cat Cracking....Jan. 169
CRECELIUS, R. L., KNIDSCHY, E. O., WHITE, E. R., COTTINGHAM, P. L., AND MURPHY, W. I. R. Recycle Hydrogenated
Shale Oil Crude....June 171
CRUMP, JOSEPH R. *See* FRENGLE, H. WILLIAM, JR.
CUMISKEY, J. E. Introduction to Principles of
Reciprocating Compressors....Nov. 120
CUNNINGHAM, W. A. *See* CRAWFORD, P. B.

**D**

DAVIS, DALE S. P-V-T for Liquid Butane....Nov. 190
DERICKSON, GAYDEN. It Pays to Organize....Nov. 183
D'ALONZO, C. A. *See* FLEMING, ALLAN J.
D'IANNI, J. D. Look Again at the Synthetic Rubber Industry..Dec. 164
DERUNGS, W. A. Controlled Corrosion Cuts Cost....Sept. 319
DONOHUE, DANIEL A Heat Exchanger Design (Part 4)....Jan. 155
DONOVAN, ROBERT G. Computers Take Over....May 138
DOWNEY, W. P. How a Rigging Sequence Is Planned....March 227
DREW, R. D. *See* BACKENSTO, E. B.
DUKLER, A. E. *See* FRENGLE, H. WILLIAM, JR.
DUNWOODY, W. E. More Ammonia with Least Investment....Dec. 169
DURANDO, ANTHONY. *See* WHITSELL, J. M.

**E**

ECKERSON, B. A., AND WALTERS, C. J.
Do You Test Heavy Hydrocarbons in Gas?....April 160
EDDY, LEE B Know Your Motor Starting Problems....Feb. 117
EDGERTON, HAROLD A. Are You a Good Interviewer?....June 232
EDISON, E. R *See* SMITH, R. B.
ELGIN, W. G. Planned Refinery Maintenance....Jan. 115
ELLIS, S. R. M. Gas Absorption Calculations....Feb. 127
ELTINGE, LAMONTE. Turbo Autos for the Future....July 138
ETHERIDGE, W. B. Think Before You Write!....May 294
ETINGEN, A. J. *See* HANNAMAN, J. R.
EVANS, G. B. *See* LACY, F. H., JR.
EVANS, H. W. *See* GALLAGHER, J. L.
EVERSON, J. W. What's the Outlook for Polyols?....Oct. 141

**F**

FAIR, ERNEST W. Five Steps to Safety....June 228
FAIRCLOUGH, HUGH. What Price Hydrogen?....Sept. 333
FEINMAN, GEORGE J. Easier Solution of
Continuous Beam Moments....Oct. 169
FINCHER, D. R. Mitigating Gasoline Plant Corrosion....March 218
FISK, CHARLES T. Preventive Maintenance—
Power Relays, Circuit Breakers....Jan. 144
FLEMING, ALLAN J., AND D'ALONZO, C. A.
Where Do We Go from 65?....Oct. 229
FLOOD, MERRILL M. This Is Operations Research....Feb. 100
FORBES, M. C. Cooling Water Filters Save Money....April 185
FRIES, HERBERT C. This Refinery Went Underground....May 225
FRITZ, E. G. Take Stock of Radioactivity....May 201
FROST, E. L. K. What Makes an Employe Tick?....Oct. 220
FULLER, A. L. Computer Evaluates Cooling Tower....Dec. 211

**G**

GAFFNEY, BERNARD J. Econograph—For Fast Analysis....Aug. 111
GALLAGHER, J. L., AND EVANS, H. W.
Compressor Cylinders Without Cooling?....Jan. 174
GERALD, C. F. Unifining-Platforming in One Unit....May 216
GHORMLEY, E. L. How to Size an Unloading Compressor....May 211
GILMORE, JOHN F. Estimate Tomorrow's Cost
from Today's Records....Oct. 175
GIVENS, HOMER C. Store LPG in a Gas Sand?....Oct. 145
GOOD, LOUIS G. How Automation Affects Maintenance Costs..May 213
GOTH, P. E., JR. *See* BROSAMER, R. J.
GRIMES, OTHA H. Stroud Plant—Portability
With Easy Construction....June 152
GROSBERG, J. S., AND MAPSTONE, GEORGE E.
Vapor Yields on Flashing....April 208
GUTZWILLER, JAMES E. Cooling Tower Fan Gear Drives....March 189

**H**

HANNAMAN, J. R., AND ETINGEN, A. J.
Union Flares Blowdown Without Smoke....Feb. 141
HARBERT, W. D. Is Your Distillation Column in Balance?....Nov. 151
HART, W. B. How New Is the Disposal Problem?....May 181
HATCH, LEWIS F. Sulfur Compounds from Petroleum....Feb. 138
Nitrogen Compounds from Petroleum....Aug. 147
Petrochemicals from Ammonia....Dec. 145
First Complete Story on Hydrogen Peroxide....March 145
HERP, HEINRICH. *See* VOGRIN, C. M.
HEFLER, JOHN R. Figure NPSH for Proportioning Pumps....June 161
HELDMAN, J. D., KUNREUTHER, F., MARSHALL, J. A., AND
REHBEIN, C. A. Cat Cracking Now in Two-Stages....May 166
HIGHFILL, W. E. Esso Installs 34.5 KV Station Switchgear...May 196
HILL, ROBERT D. What Petrochemical Plants Cost....Aug. 106
HILLYER, JACK C., AND STALLINGS, P. S.
Growing Fast—Butadiene Material of the Future....Dec. 157
HIPKIN, H. G. *See* MYERS, H. S.
HOFFMAN, DWIGHT S., AND WEBER, JAMES H.
Equilibrium Data on Ammonia....Oct. 163
Need More Data on $H_2S$?....March 213
HOLLAND, C. D., AND WOODHAM, J. F.
Continuous Vacuum Rotary Filters....Feb. 149
HOLMES, VOLNEY M. Compare Engine Fuel Costs....Jan. 164
HOOT, W. F. Need Hydrogen Compressibility Fast?....March 150
HSIAO, K. HAO. New Method for Pipe Stresses (Part 3)....Feb. 153
HUFF, RUBLE L. Texas Gas Recovers More LPG....May 194
HULL, R. J. *See* ARNOLD, M. L.
HUTCHISON, A. W., AND STEVENS, R. G.
Petrochemicals in Canada....Jan. 161
HYLTON, J. L. You Can Cut Blower Maintenance Cost....Jan. 136

**J**

JACOBS, J. K. An Easy Way to Design Packed Columns....June 187
JACKSON, WARREN, JR. *See* BURHANS, RALPH W.
JAGGARD, NORTON, AND JOHNSON, E. R. Aramco's Fluid
Hydroformer Produce 92.5 Clear Octane....Aug. 157
JOHNSON, E. R. *See* JAGGARD, NORTON
JOHNSON, WAYNE A. Save Tanks With Cathodic Protection..March 216
JOHNSON, W. B. Coal Beats Oil Here....Dec. 222
JOHNSTON, W. F. *See* WHITE, PHILIP C.
JONES, H. R. *See* PARKER, F. DRAKE
JORDAN, D. G. How to Scale Up Pilot Plant Data....June 129
JULIAN, J. J., AND SCHAEFER, R. A.
How to Reduce Compressor Downtime....Jan. 129

**K**

KAROL, R. H. Rapid Design of Pipe Supports....April 195
KATZEN, RAPHAEL. What's Ahead for
Petrochemicals During 1957....Dec. 122
KAY, HERBERT. What Hydrogen Treating Can Do....Sept. 306
KEMP, L. C., JR. Research Committee Reports....May 178
KERN, D. Q., AND ASSOCIATES.
Compare Exchanger Costs Quickly....Aug. 128
KIDD, HARRY L. Why Human Relations?....Aug. 98
KIGUCHI, S. T., AND RIDGWAY, R. L.
Superfractionator Design Considerations....Dec. 179
KILMER, J. W., RAHMES, M. H., AND LAWLER, H. L.
How to Stop Corrosion in Sulfur Plants....July 182
KING, GORDON R. How to Reduce Hydrogen Attack....Jan. 124
What Causes Hydrogen Attack....March 155
KINSELLA, HARRY E. Operations-Maintenance Coordination....Jan. 241
KISER, G. E. How to Plan and Control Capital Expenditures..Aug. 200
KITTERMAN, LAYTON, AND BARRY, CHARLES B.
This New Plant Is Semi-Automatic....April 180
KNIDSCHY, E. O. *See* CRECELIUS, R. L.

KOHL, A. L., AND RISSENFELD, F. C.
Gas Conditioning Today (Part 2)....Feb. 133
KOLAR, ROBERT J. Keep Your Motor Running....Oct. 172
KUIVINEN, T. O. Mechanical Design of Reciprocating Compressors....Nov. 124
KUNREUTHER, F. *See* HELDMAN, J. D.

L

LACY, F. H., JR., AND EVANS, G. B.
Ropes Plant . . . Low-Volume, Rich with a Long Life.June 147
LATHINER, ALFRED. Accident Control Through Supervision....July 254
LAVINE, IRVINE. *See* ZIMMERMAN, O. T.
LAWLER, H. L. *See* KILMER, J. W.
LEONARD, JACKSON D. Accounting Is an Effective Maintenance Tool....Jan. 229
LINDEN, H. R., AND REID, J. M.
New Data for Making Petrochemicals....June 189
LINEHAN, R. W. Propane Market—What You Should Know..April 163
LINTON, W. L. Mold Your Own Leaders....Feb. 205
LOCKHART, FRANK J. Drainage Time of Bubble-Cap Columns.Nov. 165
LOCKWOOD, PAUL. Showmanship Can Prevent Accidents....Feb. 212
LOHRENZ, JOHN. Find Absolute Viscosity by Nomograph....Nov. 169
LOHSE, A., AND MALLATT, R. L. How to Avoid Power Failure.Jan. 108
LONG, J. FRANK. How to Steam Trace Refinery Piping....July 187
LUDWIG, E. E. How to Specify High Pressure Vessels....Aug. 108

Mc

MCALLEN, R. A. *See* AKERS, W. W.
MCGILL, H. A., AND ZYLKS, J. M.
Planning Pays in Tubing Maintenance....Jan. 140
MCGUIRE, P. J., AND PRICE, H. A.
New Way to Clean Up Fuels....Feb. 125
MCKETTA, J. J. *See* THOMASSON, R. L.
MCKETTA, J. J. *See* PONDER, THOMAS C.
MCKINLEY, CLYDE. New Separation Tool—Low Temperature...Dec. 201
MCWHIRTER, W. E., JR., TUSSON, J. R., AND PARKER, H. A.
Destrehan Model IV Fluid Cat Cracker....April 201

M

MACHIN, L. E. Here's How Bahrain Is Maintained....Jan. 133
MALLATT, R. L. *See* LOHSE, A.
MAPSTONE, GEORGE E. Synthetic Fuels Justified in Africa....Oct. 153
MAPSTONE, GEORGE E. *See* GROSBERG, J. S.
MARKS, DEWEY. *See* ORR, A. R.
MART, E. L. *See* BALS, E. S.
MEKLER, L. A., AND UNGAR, E. E.
Nomograph for Combustion Calculations....June 157
MEKLER, L. A. How to Instrument a Heater....Sept. 223
MEYER, RONALD E. New Avenue for Capital Oxidation of LPG?....Dec. 172
MILLER, J. E. *See* ULLRICH, G. F.
MING, E. T., AND BOTT, L. L.
Metals Affect Distillate Stability....April 192
MITCHELL, R. L. Make Petrochemicals from Air and LPG....July 179
MONTGOMERY, C. W. *See* WEINBERGER, E. B.
MONTGOMERY, W. J. *See* WHITE, PHILIP C.
MOORE, L. W. Octanes Over 100—Here's Why It's Important to the Refiner and the Case for Performance Numbers.July 162
MORTENSON, TAGE A. How Operations Research Aids the Refiner....Dec. 126
MORTON, B. B. M-O-C for Hydrogen....March 164
MOXEY, J. G., JR. What Will Gasoline Be Like in 1960?....May 230
MURPHY, W. I. R. *See* CHECELIUS, R. L.
MYERS, H. S., AND HIPKIN, H. G. Fast Butane Analysis....July 175

N

NEUMAIER, B. W., AND SCHILLMOLLER, C. M.
Design for Minimum Corrosion....May 146
NEWTON, E. C., AND CONETTA, M. A.
How Maintenance Costs Can Be Controlled....March 221
NORRIS, BERRY E. *See* PRENGLE, H. WILLIAM

O

OLIVE, M. J. Cathodic Protection Pays Off Here....April 188
ORR, A. R., AND MARKS, DEWEY.
Newest Olefin Polymer—Polbutene....Dec. 185
OTTEN, PHILIP S. How to Specify a Heat Exchanger....Oct. 116

P

PARKER, F. DRAKE, AND JONES, H. R.
Don't Forget Markets in Plant Design....Dec. 187
PARKER, H. A. *See* MCWHIRTER, W. E., JR.
PATON, BRUCE L. Do Models Pay Out?....Nov. 161
PAYNE, JOHN W. When to Use a Pilot Plant....June 126
PERKINS, GERALD. *See* WEST, PHILIP W.
PHILLIPS, R. J. New Process for Removing Reformer Feed Stock Sulfur....Nov. 202
PODBIELNIAK, WALTER J., AND PRESTON, SEATON T.
Vapor-Phase Chromatography....April 215
POLL, HARRY F. What Unifining Can Do for You....July 193
PONDER, THOMAS C. To Get More Plant for Less Money....Oct. 106
PONDER, THOMAS C., AND MEKETTA, J. J.
Petrochemicals in Synthetic Fibers....Feb. 109
PONDER, THOMAS C. *See* THOMASSON, R. L.
POWERS, M. L. Automation—What It Means....Jan. 253
PRATER, NILON H. Estimate Gasoline Yields from Crudes....May 236
PRENGLE, H. WILLIAM, JR., DUKLER, A. E., CRUMP, JOSEPH R., AND NORRIS, BERRY E. What's the Lower Limit for Gas Processing....April 141
PRESTON, SEATON T. *See* PODBIELNIAK, WALTER J.
PRICE, H. A. *See* MCGUIRE, P. J.
PRINGLE, JAMES T. Contractor's Reaction to RP-500....May 151
PYEATT, W. W. Claytonville Plant Portability Was Not the Goal....June 145

R

RAHMES, M. H. *See* KILMER, J. W.
RALPH, H. F. *See* AKERS, W. W.
RAMSEY, C. S. Control the Slurry in Copper Sweetening....June 186
REHBEIN, C. A. *See* HELDMAN, J. D.
REID, J. M. *See* LINDEN, H. R.
RENDEL, T. B. New Developments in Antiknock Scales....July 170
RIDGWAY, R. L. *See* KIGUCHI, S. T.
RIDGWAY, ROBERT S. Installation, Operation and Maintenance of Reciprocating Compressors....Oct. 137
RISSENFELD, F. C. *See* KOHL, A. L.
ROLL, KEMPTON H. How to Maintain and InspectLeadLinings.Nov. 19
RUBIN, FRANK L. Find Properties of Hydrogen Mixtures....March 140

S

SACHS, A. P. *See* ARIES, R. S.
SAGER, F. New Yugoslavian Refinery Uses Combination Approach....Sept. 230
SAMPSON, O. A. *See* AKERS, W. W.
SCHAAD, RAYMOND E. Depolymerize Butene Trimers....March 205
SCHAEFER, H. A. *See* JULIAN, J. J.
SCHILLMOLLER, C. M. *See* NEUMAIER, B. W.
SCHRAGE, ROBERT W. *See* DONOVAN, ROBERT G.
SEXTON, WILLIAM E. Streamline Your Office Work....Sept. 402
SHERMAN, JACK. Use Computers For Refining Problems....May 139
SHERWOOD, PETER W. Here's the Complete Story on This Petrochemical Pentaerythritol....Nov. 171
Look Carefully at Acrolein....Dec. 151
SMITH, A. N. How Effective Is Your Maintenance Dollar?
(Part 1)....Jan. 104
(Part 2)....Feb. 126
(Part 3)....March 225
SMITH, CECIL W Taking Stock....(Monthly Feature)
Take a Look at 1956....Jan. 152
SMITH, ENNIS C. How to Specify Cooling Towers....Oct. 125
SMITH, R. B., AND EDISON, R. R.
What Are Heater Tubes Worth?....Aug. 123
SNELL, FOSTER DEE. Here's the Outlook for Syndets....Dec. 139
SNIFFEN, TED J. How to Select and Install Pump Seals....March 207
SOMERS, F. C. A Refiner's Reaction to RP-500....June 202
STALLINGS, P. S. *See* HILLYER, JACK C.
STAPLEFORD, C. C. *See* BACKENSTO, E. B.
STEVENS, ROBLEY D. How Do Your Supervisors Rate?....May 276
STEVENS, R. G. *See* HUTCHISON, A. W.
STICHA, E. A. Which Steel for High Temperature Piping....Nov. 185
STRELZOFF, S. Fortier Plant of American Cyanamid....March 167
STRYKER, JOHN E. How to Specify a Compressor....Oct. 119
SUE, JOHN O. What's Happening to Gas Contracts?....April 151
SUTER, HANS A. *See* WEST, PHILIP W.
SWANTON, W F. How to Specify a Column....Oct. 113
SWEARINGEN, JUDSON S. Estimating Research Costs....June 124

T

TALLEY, ENOCH. Are Explosion-Proof Motors Necessary?....Nov. 180
THOEN, J. O. Dollar Value of Human Relations....May 218
THOMAS, B. W., AND BEAUGH, J. B. Continuous Monitors Developed for Reforming and Dewaxing....Oct. 123
THOMASSON, R. L., MCKETTA, J. J., AND PONDER, T. C.
Which Polyethylene Process....Dec. 191
THORNE, H. M. Retort Oil Shale for Chemicals....July 155
THORNTON, D. P., JR. What to Avoid in Scale-Up....June 126
TRICKETT, JOSEPH H. Management's 'Forgotten Men'....July 262
TUCKER, WILLIAM E. Want Refinery Costs Quickly?....Aug. 100
TUSSON, J. R. *See* MCWHIRTER, W. E., JR.
TYER, DAVID F. The Engineer in Management....April 275

U

ULLRICH, G. F., AND MILLER, J. E.
Low Cost Water Effluent Separator....March 211
UNGAR, E. E. *See* MEKLER, L. A.

V

VAN NESS, HENDRICK C.
Thermodynamics for Process Evaluation....Jan. 165
What Hydrogen Does to Metals....March 160
VLACHOS, J. N. *See* BACKENSTO, E. B.
VOGRIN, C. M., AND HEEP, . . JENRICH.
New Tests on Castables....Feb. 158

W

WALTER, JOHN T. How Reliable are Lab Analyses?....Feb. 106
WALTERS, C. J. *See* ECKERSON, B. A.
WEATHERBY, J. J. Adena Plant Uses No Water....April 175
Air Versus Water Cooling....March 181
WEBER, JAMES H. *See* HOFFMAN, DWIGHT S.
WEINBERGER, E. B., AND MONTGOMERY, C. W.
Equilibrium for $C_4$'s and Hydrogen....May 141
WEINRICH, W. WHITNEY. *See* COX, JOHN T., JR.
WENDER, IRVING. Here are Complete OXO Reaction Data....Dec. 197
WEST, PHILIP W., SUTER, HANS A., AND PERKINS, GERALD
Better Ash Determination....May 230
WESTER, R. E. *See* BALS, E. S.
WHITE, E. R. *See* CHECELIUS, R. L.
WHITE, PHILIP C., JOHNSTON, W. F., AND MONTGOMERY, W. J.
Ultraform to Get 100 Octane Clear....May 171
WHITESELL, J. M., AND DURANDO, ANTHONY
Revitalize Your Tower....March 156
WIESE, WARREN M.
The Other Side—Extend Present Octane Scale....July 166
WILCOX, WILLIAM S. Why Suggestion Systems?....Sept. 410
Pin Pricks from Within....March 274
Open the Door to Non-Union Employes?....Oct. 240
Are Your 'Communications' Showing?....Nov. 244
WILLARD, BLAIR J. Up-to-Date on Plant Instrumentation....April 170
WILLIAMS, THEODORE J.
Automation Today (Part 1)....April 211
Automation Today (Part 2)....May 205
Automation Today (Part 3)....June 141
Automation Today (Part 4)....July 149
Automation Today (Part 5)....Aug. 161
Automation Today (Part 6)....Sept. 236
WILSON, ROBERT E. Will Atomic Energy Replace Oil?....Nov. 118
WINFREY, J. C. New Method for Vapor Pressure....Nov. 205
WINN, FRANCIS W. Nomograms . . . Make Your Own
(Part 2)....Feb. 121
(Part 4)....March 171
How to Invest Your Capital for Profits....July 199

WINSTON, R. E., AND CLARKE, LOYAL.
Easy Way to Determine Heat Transfer Coefficients..May 277
WISE, WILLIAM M. Preventive Maintenance of Process Pumps..Jan. 121
WOODHAM, J. E. *See* HOLLAND, C. D.
WOODWARD, E. R. Hydrazine Cuts Water Treating Costs.....Dec. 208
WORRELL, G. RICHARD. Now 100 Octane from Natural.....April 133

Z

ZAHNSTECHER, L. W. *See* BRANDON, A.
ZIMMERMAN, O. T., AND LAVINE, IRVIN.
Want Equipment Costs for Estimates?.....Aug. 116
ZULKE, J. M. *See* MCGILL, H. A.

# SUBJECT INDEX
## PETROLEUM REFINER

**VOLUME 35—1956**

A

Absorption Calculations, Gas.....Feb. 127
Accident Control Through Supervision. Alfred Lateiner....July 254
Accidents, Showmanship Can Prevent.....Feb. 212
Accidents, What Causes.....Aug. 212
Accounting Is an Effective Maintenance Tool. Jackson D. Leonard.....Jan. 229
Acrolein, Look Carefully at.....Dec. 151
ADC Ferrocyanide Treating.....Sept. 275
Additives, A Big Business—Lube Oil.....May 235
Adena Plant Uses no Water. J. J. Weatherby.....April 175
Africa, Synthetic Fuels Justified in.....Oct. 159
Airlift TCC.....Sept. 228
Air Pollution Help, Here's.....Aug. 156
Air Versus Water Cooling. J. J. Weatherby.....March 181
ALKYLATION
Make High Octane Alky for Motor Fuel.....July 192
Processes.....Sept. 246
Aluminum Chloride Alkylation.....Sept. 248
American Cyanamid, Fortier Plant of.....March 167
Ammonia, Equilibrium Data on.....Oct. 163
Ammonia, Petrochemicals from.....Dec. 145
Ammonia with Least Investment, More.....Dec. 169
ANALYSIS
Antiknock Scales—Here's Why It's Important to the Refiner and the Case for Performance Numbers.....July 162
Antiknock Scales—The Other Side—Extend Present Octane Scale.....July 166
Better Ash Determination.....May 220
Check Effluent With Bioassay.....June 197
Do You Test Heavy Hydrocarbons in Gas?.....April 160
Fast Butane Analysis.....July 175
Fuel Gas Analysis by Chromatography?.....Nov. 197
How Reliable Are Lab Analyses?.....Feb. 106
New Development in Antiknock Scales.....July 170
New Method for Vapor Pressure.....Nov. 205
Research Committee Reports.....May 178
Take Another Look at Charcoal Test.....April 166
Trace Analysis Catches Up.....May 184
Vapor-Phase Chromatography.....April 215
Antiknock Scales—Here's Why It's Important to the Refiner and the Case for Performance Numbers. L. W. Moore...July 162
Antiknock Scales—The Other Side—Extend Present Octane Scale. Warren M. Wiese.....July 166
Aramco's Fluid Hydroformer Produce 92.5 Clear Octane. Norton Jaggard and E. R. Johnson.....Aug. 157
Are Explosion-Proof Motors Necessary? Enoch Talley.....Nov. 180
Are You a Good Interviewer? Harold A. Edgerton.....June 232
Are You Tense?.....March 282
Are Your 'Communications' Showing? William S. Wilcox..Nov. 244
Are Your Employe Communications Effective? Alan A. McLean.....June 228
Ash Determination, Better.....May 220
Atomic Energy Replace Oil, Will?.....Nov. 118
Autofining.....Sept. 276
Automation Affects Maintenance Cost, How.....May 213
Automation Today (Part 1). Theodore J. Williams.....April 211
Automation Today (Part 2). Theodore J. Williams.....May 205
Automation Today (Part 3). Theodore J. Williams.....June 141
Automation Today (Part 4). Theodore J. Williams.....July 149
Automation Today (Part 5). Theodore J. Williams.....Aug. 161
Automation Today (Part 6). Theodore J. Williams.....Sept. 336
Automation—What it Means. M. L. Powers.....Jan. 253

B

Bahrain Is Maintained, Here's How.....Jan. 133
Baytown Refinery Virtually Rebuilt.....June 122
Beam Moments, Easier Solution of Continuous.....Oct. 169
Bender.....Sept. 277
Better Ash Determination. Philip W. West, Hans A. Suter and Gerald Perkins.....May 220
Bioassay, Check Effluent With.....June 197
Blowdown Without Smoke, Union Flares.....Feb. 143
Blower Maintenance Cost, You Can Cut.....Jan. 136
'Blueprint' for Retirement.....Feb. 202
Boiler Water Treatment, Simplify.....Nov. 193
Breakers, Preventive Maintenance—Power Relays Circuit..Jan. 144
Bubble-Cap Columns, Drainage Time of.....Nov. 165
Butadiene Material of the Future, Growing Fast.....Dec. 157
Butane Analysis, Fast.....July 175
Butane, P-V-T for Liquid.....Nov. 190
Butane Vapor-Phase Isomerization.....Sept. 252
Butene Trimers, Depolymerize.....March 205

C

$C_3$ and $C_4$ with Penex, Isomerize.....July 148
$C_4$'s and Hydrogen, Equilibrium for.....May 141
CALCULATION METHODS
Computer Evaluates Cooling Towers.....Dec. 211
Drainage Time of Bubble-Cap Columns.....Nov. 165
Easier Solution of Continuous Beam Moments.....Oct. 169
Easy Way to Design Packed Columns.....June 187
Gas Absorption Calculations.....Feb. 127
How to Scale Up Pilot Plant Data.....June 129
Is Your Distillation Column in Balance?.....Nov. 151
Nomograph for Combustion Calculations.....June 157
There's a Limit to Use of Equations of State.....Feb. 113
Thermodynamics for Process Evaluation.....Jan. 165
Vapor Yields on Flashing.....April 208
California Polymerization.....Sept. 258
Canada, Petrochemicals in.....Jan. 161
Capital Expenditures, How to Plan and Control.....Aug. 200
Carbon Formation in Cat Cracking. P. B. Crawford and W. A. Cunningham.....Jan. 169
Castables, New Tests on.....Feb. 158
CATALYTIC CRACKING (*See* CRACKING)
Catalytic Isomerization.....Sept. 253
Catforming.....Sept. 206
Cathodic Protection Pays Off Here. M. J. Olive.....April 188
Cathodic Protection, Save Tanks with.....March 216
Centrifugal Pumps, How to Select.....Sept. 341
Check Effluent With Bioassay. Howard P. Clemens and Charles Clough.....June 197
Check This Plant's Pumping System. R. W. Bucklin.....April 155
Chemical Desalting.....Sept. 278
Chromatography, Fuel Gas Analysis by.....Nov. 197
Claytonville Plant . . . Portability Was Not the Goal. W. W. Pyeatt.....June 145
Clean Up Fuels, New Way to.....Feb. 125
Coal Beats Oil Here. W. B. Johnson.....Dec. 222
Coke & Gasoline, New Material for.....Aug. 153
Coke for Power, New Refinery Trades.....Aug. 141
Coking.....Sept. 240
Column in Balance, Is Your Distillation.....Nov. 151
Column, How to Specify a.....Oct. 113
Columns, Drainage Time of Bubble-Cap.....Nov. 165
Combination Cracking.....Sept. 243
Combination Unit.....Sept. 244
Combustion Calculations, Nomograph for.....June 157
'Communications' Showing, Are Your.....Nov. 244
Compare Engine Fuel Costs. Volney M. Holmes.....Jan. 164
Compare Exchanger Costs Quickly. D. Q. Kern & Associates.....Aug. 128
Compressibility Factor of Mixtures. W. W. Akers and J. D. Burns.....March 154
Compressibility Fast, Need Hydrogen.....March 150
COMPRESSORS
How to Specify a Compressor.....Oct. 119
Compressor Trouble-Shooting.....Nov. 149
How to Size an Unloading Compressor.....May 211
How to Reduce Compressor Downtime.....Jan. 129
Installation, Operation and Maintenance of Reciprocating Compressors.....Nov. 137
Introduction to Principles of Reciprocating Compressors.Nov. 120
Mechanical Design of Reciprocating Compressors.....Nov. 124
Performance Characteristics of Reciprocating Compressors.....Nov. 129
You Can Cut Blower Maintenance Cost.....Jan. 136
Compressor Cylinders without Cooling.....Jan. 174
Computers Evaluate Cooling Towers, A. L. Fuller.....Dec. 211
Computers for Refining Problems, Use.....May 139
Computers Take Over. Robert G. Donovan and Robert W. Schrage.....May 138
Computing Cooling Tower Performance. Maxey Brooke..March 183
Condensers, Design of Cooler.....June 177
CONSTRUCTION
Baytown Refinery Virtually Rebuilt.....June 122
Do Models Pay Out?.....Nov. 161
Estimate Tomorrow's Cost from Today's Records.....Oct. 175
$560 Million Postwar Expansion Program.....Jan. 100
How a Rigging Sequence Is Planned.....March 227
How a Small Refinery Grew.....Oct. 104
M-O-C for Hydrogen.....March 164
New Look at Free World Expansion.....April 266
New Yugoslavian Refinery Uses Combination Approach.Sept. 330
Petrofina Expands Refining Operation on Three Continents.....Nov. 256
Phillips Gears Operation for Wide Diversification.....Sept. 194
Refinery Integrates Three Hydrofiners.....Oct. 166
Socony Mobil's Greatest Expansion Period.....Feb. 98
Standard-Vacuum's Postwar Construction.....March 270
Two Jersey Affiliates Build to Meet Postwar Demands..July 134
Continuous Contact Filtration.....Sept. 279
Continuous Monitors Developed for Reforming and Dewaxing. B. W. Thomas and J. B. ...augh.....Oct. 133
Continuous Vacuum Rotary Filters. C. D. Holland and J. F. Woodham.....Feb. 149
Contractor's Reaction to RP-500. James T. Pringle.....May 151
Contracts, What's Happening to Gas.....April 151
Control Capital Expenditures, How to Plan and.....Aug. 200
Control the Slurry in Copper Sweetening. C. S. Ramsey...June 186
Controlled Corrosion Cuts Cost. W. A. Derungs.....Sept. 319
COOLING (*See* HEAT TRANSFER)
Cooling, Air Versus Water.....March 181
Cooling Design, Simplify Gas.....March 191
Cooling Tower Fan Gear Drives. James E. Gutzwiller...March 189
Cooling Tower Performance, Computing.....March 183
Cooling Towers, Computers Evaluate.....Dec. 211
Cooling Towers, How to Specify.....Oct. 125
Cooling Water Filters Save Money. M. C. Forbes.....April 185
Copper Sweetening, Control the Slurry in.....June 186

CORROSION
Cathodic Protection Pays Off Here....April 183
Controlled Corrosion Cuts Cost....Sept. 319
Design for Minimum Corrosion....May 146
How to Reduce Hydrogen Attack....Jan. 124
How to Stop Corrosion in Sulfur Plants....July 183
Hydrogen Sulfide Corrosion in Sovaformers....Aug. 165
Mitigating Gasoline Plant Corrosion....March 218
Save Tanks With Cathodic Protection....March 216
What Happens in Hydrogen-Hydrogen Sulfide Corrosion..Jan. 147
Cost Analyses, Econograph . . . for Fast....Aug. 111
Cost, Controlled Corrosion....Sept. 319
Cost from Today's Records, Estimate Tomorrow's....Oct. 175
Cost, What Petrochemical Plants....Aug. 106
Costs for Estimates, Want Equipment....Aug. 116
Costs Quickly, Compare Exchanger....Aug. 128
Costs Quickly, Want Refinery....Aug. 100
CRACKING, CATALYTIC
Carbon Formation in Cat Cracking....Jan. 169
Destrehan Model IV Fluid Cat Cracker....April 201
Cat Cracking Now in Two Stages. J. D. Heldman, F. Kunreuther, J. A. Marshall, C. A. Rehbein....May 166
More Cat Cracking Feed....Nov. 160
Processes....Sept. 227
Crude Distillation for Maximum Cracking Feed....Sept. 301
Crude Distillation for Maximum Lubes....Sept. 302
Cycloversion....Sept. 208

D

Decarbonizing....Sept. 240
Delayed Coking....Sept. 240
Demand to Increase One-Third in Five Years, World....Sept. 426
Depolymerize Butene Trimers, Raymond E. Schaad....March 205
Design of Cooler Condensers, G. H. P. Bras....June 177
Design for Minimum Corrosion, B. W. Neumaier and C. M. Schillmoller....May 146
Designing an Electric Power System, N. A. Austin....March 201
Destrehan Model IV Fluid Cat Cracker, W. E. McWhirter, Jr., J. R. Tusson and H. A. Parker....April 201
DESULFURIZATION (*See* TREATING)
Dewaxing, Continuous Monitors Developed for....Oct. 133
DIESEL FUEL
National Diesel Fuel Survey—1955....March 196
Dieselforming....Sept. 280
Design Direct Contact Coolers Quickly, G. H. P. Bras....Dec. 215
DISTILLATION (*See* FRACTIONATION)
Doctor Sweetening....Sept. 281
Dollar Value of Human Relations, J. O. Thoen....May 218
Do Models Pay Out? Bruce L. Paton....Nov. 161
Do You Test Heavy Hydrocarbons in Gas? B. A. Eckerson and C. J. Walters....April 160
Don't Forget Markets in Plant Design. F. Drake Parker and H. R. Jones....Dec. 187
Drainage Time of Bubble-Cap Columns. Frank J. Lockhart....Nov. 165
Dualayer Distillate Process....Sept. 282
Dualayer Gasoline Process....Sept. 283
Duo-Sol....Sept. 262

E

Easier Solution of Continuous Beam Moments. George J. Feinman....Oct. 169
Easy Way to Design Packed Columns, J. E. Jacobs....June 137
Easy Way to Determine Heat Transfer Coefficients. R. E. Winston and Loyal Clarke....May 227
Econograph . . . for Fast Cost Analyses. Bernard J. Gaffney....Aug. 111
ECONOMICS
Accounting Is an Effective Maintenance Tool....Jan. 229
Compare Exchanger Costs Quickly....Aug. 128
Econograph . . . for Fast Cost Analyses....Aug. 111
Estimate Tomorrow's Cost from Today's Records....Oct. 175
Estimating Research Cost....June 124
How Effective Is Your Maintenance Dollar? (Part 1) A. N. Smith....Jan. 104
How Effective Is Your Maintenance Dollar? (Part 2)....Feb. 135
How Effective Is Your Maintenance Dollar? (Part 3)..March 225
How Maintenance Costs Can Be Controlled....March 221
How to Invest Your Capital for Profits....July 199
How to Plan and Control Capital Expenditure....Aug. 200
How to Specify a Compressor....Oct. 119
How to Specify a Column....Oct. 113
How to Specify Cooling Towers....Oct. 125
How to Specify a Heat Exchanger....Oct. 116
How to Specify High Pressure Vessels....Oct. 108
More Ammonia with Least Investment....Dec. 169
New Avenue for Capital . . . Oxidation of LPG....Dec. 172
New Separation Tool—Low Temperature....Dec. 201
Refined Products Outlook for 1957....Oct. 130
Synthetic Fuels Justified in Africa....Oct. 159
To Get More Plant for Less Money....Oct. 106
Want Equipment Costs for Estimates?....Aug. 116
Want Refinery Costs Quickly?....Aug. 100
What Are Heater Tubes Worth?....Aug. 133
What Petrochemical Plants Cost....Aug. 106
What Price Hydrogen?....Sept. 333
Will Atomic Energy Replace Oil?....Nov. 118
World Demand to Increase One-Third in Five Years....Sept. 426
Effluent Refrigeration Alkylation....Sept. 249
Electric Desalting (Petreco)....Sept. 284
Electric Power System, Designing an....March 201
Electrical Desalting (Howe-Baker)....Sept. 285
Electrical Distillate Treating....Sept. 286
Electrofining....Sept. 287
Electrolytic Mercaptan....Sept. 288
Employing the College Graduate....March 136
Engineer in Management, David F. Tver....April 275
Engineers, Maintenance Needs....Jan. 120
Equations of State, There's a Limit to Use of....Feb. 113
Equilibrium Data on Ammonia, James H. Weber and Dwight S. Hoffman....Oct. 163
Equilibrium for $C_3$'s and Hydrogen, E. B. Weinberger and C. W. Montgomery....May 141
EQUIPMENT (*See also* COMPRESSORS, PUMPS, HEAT EXCHANGERS and INSTRUMENTATION)
Are Explosion-Proof Motors Necessary?....Nov. 180
How to Select the Right Pump Motor....Oct. 159
How to Specify Cooling Towers....Oct. 125
How to Specify a Column....Oct. 113
How to Specify High Pressure Vessels....Oct. 108
To Get More Plant for Less Money....Oct. 106
Want Equipment Costs for Estimates?....Aug. 116
Esso Installs 34.5 KV Station Switchgear, W. E. Highfill..May 196
Estimate Gasoline Yields from Crudes, Nilon H. Prater....May 236
Estimate Tomorrow's Cost from Today's Records. John F. Gilmore....Oct. 175
Estimates, Want Equipment Costs for....Aug. 116
Estimating Research Cost, Judson S. Swearingen....June 124
EXCHANGERS (*See* HEAT TRANSFER)
Expansion Period, Socony Mobil's Greatest....Feb. 98
Explosion-Proof Motors Necessary, Are....Nov. 180

F

Fast Butane Analysis, H. S. Myers and H. G. Hipkin....July 175
Fibers, Petrochemicals in Synthetic....Feb. 109
Figure NPSH for Proportioning Pumps, John R. Hefler...June 161
Filters, Continuous Vacuum Rotary....Feb. 149
Filters Save Money, Cooling Water....April 185
Find Absolute Viscosity by Nomograph, John Lohrenz....Nov. 169
Find Properties of Hydrogen Mixtures, Frank L. Rubin..March 140
Find Reasons for Unsafe Acts....Sept. 428
Find Specific Heat Fast, W. W. Akers and H. F. Ralph..March 151
FIRES
Are Explosion-Proof Motors Necessary?....Nov. 180
How to Hold Down Fire Losses....April 134
Five Steps to Safety, Ernest W. Fair....June 238
Five Ways to Safety....Jan. 256
$660 Million Postwar Expansion Program....Jan. 100
First Complete Story on Hydrogen Peroxide. Louis F. Hatch....March 197
FLUID CATALYTIC CRACKING (*See also* CRACKING)
Fluid Catalytic Cracking (Esso)....Sept. 230
Fluid Catalytic Cracking (Kellogg)....Sept. 232
Fluid Catalytic Cracking (Shell)....Sept. 234
Fluid Catalytic Cracking (UOP)....Sept. 236
Fluid Coking....Sept. 242
Fluid Hydroformer Produce 92.5 Clear Octane, Aramco's..Aug. 157
Fluid Hydroforming (Esso)....Sept. 224
Fluid Hydroforming (Kellogg)....Sept. 210
Forecast: $20.1 Billion Outlay by 1965....Feb. 152
Fortier Plant of American Cyanamid, S. Streizoff....March 167
FRACTIONATION
Estimate Gasoline Yields from Crudes....May 236
Is Your Distillation Column in Balance?....Nov. 151
New Separation Tool—Low Temperature....Dec. 201
Superfractionator Design Considerations....Dec. 179
From Chaos to Europe's Leading Refiner....Dec. 280
Fuel Costs, Compare Engine....Jan. 164
Fuel Gas Analysis by Chromatography? Vincent J. Coates and Nathaniel Brenner....Nov. 197
Fuel Injection Changes Emphasis, A. E. Cleveland....July 145
FUEL OIL
Metals Affect Distillate Stability....April 192
Fuels Justified in Africa, Synthetic....Oct. 159
Furfural Extraction of Gas Oils....Sept. 263
Furfural Refining....Sept. 264

G

Gas Absorption Calculations, S. R. M. Ellis....Feb. 127
Gas Conditioning Today (Part 2), A. L. Kohl and F. C. Riesenfeld....Feb. 133
GASOLINE
New Method for Vapor Pressure....Nov. 205
Now 100 Octane from Natural....April 138
Synthetic Fuels Justified in Africa....Oct. 159
What Will Gasoline Be Like in 1960?....May 230
GASOLINE PLANTS
Adena Plant Uses No Water....April 175
Check This Plant's Pumping System....April 156
Claytonville Plant . . . Portability Was Not the Goal..June 145
Ropes Plant . . . Low-Volume, Rich Gas With a Long Life....June 147
Texas Gas Recovers More LPG....May 194
Mitigating Gasoline Plant Corrosion....March 218
New Material for Coke and Gasoline....Aug. 153
Pemex Recovers Gas at Reynosa....April 206
Revamping a Gasoline Plant....April 148
Stroud Plant . . . Portability With Easy Construction..June 152
This Plant Is Going Modern....April 152
What's the Lower Limit for Gas Processing?....April 141
Girbotol....Sept. 289
Glycol Amine Gas Treating....Sept. 290
Grease Manufacturing....Sept. 303
Growing Fast—Butadiene Material of the Future. Jack C. Hillyer and P. S. Stallings....Dec. 187
Gulf HDS....Sept. 291

H

HEAT EXCHANGERS (*See* HEAT TRANSFER)
HEAT TRANSFER
Adena Plant Uses No Water....April 175
Air Versus Water Cooling....March 181
Compare Exchanger Costs Quickly....Aug. 128
Computing Cooling Tower Performance....March 183
Cooling Tower Fan Gear Drives....March 189
Design Direct Contact Coolers Quickly....Dec. 215
Design of Cooler Condensers....June 177
Easy Way to Determine Heat Transfer Coefficients....May 227
Exchanger Preventive Maintenance Pays, R. E. Butler and R. P. Coleman....Jan. 111
Heat Exchanger Design (Part 4), Daniel A. Donohue...Jan. 156
How to Instrument a Heater....Sept. 323
How to Specify a Heat Exchanger....Oct. 116
Revitalize Your Tower....March 186
Shorten Heat Transfer Problems....March 152
Simplify Gas Cooling Design....March 191
Snap-On Insulation....Feb. 112
What Are Heater Tubes Worth?....Aug. 133
Here are Complete OXO Reaction Data, Irving Wender...Dec. 197
Here's Air Pollution Help....Aug. 156
Here's the Complete Story on this Petrochemical—Pentaerythritol, Peter W. Sherwood....Nov. 171
Here's the Outlook for Syndets, Foster Dee Snell....Dec. 139
Here's How Bahrain Is Maintained, L. E. Machin....Jan. 132

## SUBJECT INDEX *continued*


High Pressure Vessels, How to Specify....Oct. 108
High Temperature Piping, Which Steel for....Nov. 185
Higher Octanes or Not?....July 137
High-Pressure Joints, Holding....May 189
Holding High-Pressure Joints. Walter Coopey....May 189
Houdresid....Sept. 238
Houdriflow....Sept. 238
Houdriforming....Sept. 220
How a Small Refinery Grew....Oct. 104
How Automation Affects Maintenance Cost. Louis G. Good.May 213
How Do Your Supervisors Rate? Robley D. Stevens....May 276
How Effective Is Your Maintenance Dollar?
(Part 1) A. N. Smith....Jan. 104
(Part 2)....Feb. 135
(Part 3)....March 225
How Maintenance Costs Can Be Controlled.
E. C. Newton and M. A. Conetta....March 221
How to Specify a Column. W. F. Swanton....Oct. 113
How New Is the Disposal Problem? W. B. Hart....May 181
How Operations Research Aids the Refiner.
Tage A. Mortenson....Dec. 126
How to Avoid Power Failures. A. Lohse and R. L. Mallatt.Jan. 108
How to Handle Employe Grievances. Jack B. Bedford....May 288
How to Hold Down Fire Losses....April 134
How to Instrument a Heater. L. A. Mekler....Sept. 323
How to Invest Your Capital for Profits. Francis W. Winn.July 199
How to Maintain and Inspect Lead Linings.
Kempton H. Roll....Nov. 191
How to Measure Maintenance Results. E. S. Bale,
E. L. Mast and R. E. Wester....May 159
How to Plan and Control Capital Expenditures.
G. E. Kiser....Aug. 200
How to Reduce Hydrogen Attack. Gordon R. King....Jan. 124
How to Scale Up Pilot Plant Data. D. G. Jordan....June 129
How to Select Centrifugal Pumps. Jack A. Cable....Sept. 341
How to Select the Right Pump Motor....Oct. 159
How to Size an Unloading Compressor. E. L. Ghormley...May 211
How to Specify Cooling Towers. Ennis C. Smith....Oct. 125
How to Specify a Compressor. John E. Stryker....Oct. 119
How to Specify a Heat Exchanger. Philip S. Otten....Oct. 116
How to Specify High Pressure Vessels. E. E. Ludwig....Oct. 108
How to Steam Trace Refinery Piping. J. Frank Long....July 187
How to Stop Corrosion in Sulfur Plants. J. W. Kilmer,
M. H. Rahmes and H. L. Lawler....July 183
How Reliable Are Lab Analyses? John T. Walter....Feb. 106
How to Reduce Compressor Downtime. J. J. Julian
and R. A. Schaefer....Jan. 129
How a Rigging Sequence Is Planned. W. P. Downey....March 227
How to Select and Install Pump Seals. Ted J. Sniffen...March 207
Human Relations, Dollar Value of....May 218
Human Relations, Why....Aug. 98
Hydrazine Cuts Water Treating Costs. E. R. Woodward...Dec. 208
Hydrofiners, Refinery Integrates Three....Oct. 166
Hydrofining....Sept. 292
HYDROGEN
Equilibrium for $C_5$'s and Hydrogen....May 141
Find Properties of Hydrogen Mixtures....March 140
Find Specific Heat Fast....March 151
How to Reduce Hydrogen Attack....Jan. 124
M-O-C for Hydrogen....March 164
Need Hydrogen Compressibility Fast....March 150
Pick Off Viscosity....March 153
Shorten Heat Transfer Problems....March 152
What Causes Hydrogen Attack....March 155
What Happens in Hydrogen-Hydrogen Sulfide Corrosion.Jan. 147
What Hydrogen Does to Metals....March 160
What Hydrogen Treating Can Do....Sept. 306
What Price Hydrogen....Sept. 333
Hydrogen Peroxide, First Complete Story on....March 197
Hydrogen Sulfide Corrosion in Sovaformers.
E. H. Backensto, R. D. Drew and J. N. Vlachos....Aug. 165
Hydrogen Sulfide, Need More Data on....March 213
Hydrogenated Shale Oil Crude, Recycle....June 171
Hyperforming....Sept. 225

I

Improved Human Relations. R. W. Callahan....Jan. 235
Independents Do Big Share of Oil Business....June 170
INDUSTRIAL RELATIONS
Are Your 'Communications' Showing?....Nov. 244
'Blueprint' for Retirement....Feb. 202
Dollar Value of Human Relations....May 218
Employing the College Graduate....March 136
Engineer in Management....April 275
Improved Human Relations....Jan. 235
Need Craft Apprentices? Try Personnel Tests....Dec. 266
Open the Door to Non-Union Employes?....Oct. 240
Pin Pricks from Within....March 274
Queer Quirks of the Law....Aug. 228
Streamline Your Office Work....Sept. 402
What Causes Accidents?....Aug. 212
What Makes an Employe Tick?....Oct. 220
Where Do We Go From 65?....Oct. 229
Why Human Relations?....Aug. 98
Why Suggestion Systems?....Sept. 410
Inspect Lead Linings, How to Maintain and....Nov. 191
Installation, Operation and Maintenance of
Reciprocating Compressors. Robert S. Ridgway....Nov. 137
INSTRUMENTATION
Automation Today (Part 1)....April 211
Automation Today (Part 2)....May 205
Automation Today (Part 3)....June 141
Automation Today (Part 4)....July 149
Automation Today (Part 5)....Aug. 161
Automation Today (Part 6)....Sept. 336
Continuous Monitors Developed for
Reforming and Dewaxing....Oct. 133
How Automation Affects Maintenance Cost....May 213
How to Instrument a Heater....Sept. 323
Mass Spectrometer Monitoring....March 179
This Plant Is Semi-Automatic....April 180
Up-to-Date on Plant Instrumentation....April 170
Insulation, Snap-On....Feb. 113
Introduction to Principles of Reciprocating
Compressors. J. E. Cumiskey....Nov. 120
Invest Your Capital for Profits, How to....July 199
Iron Curtain, Refining Behind the....Sept. 417
Isomate....Sept. 254
ISOMERIZATION
Isomerize $C_5$ and $C_6$ with Penex....July 148
Processes....Sept. 247
Iso-Plus Houdriforming....Sept. 221
Is Your Distillation Column in Balance? W. D. Harbert...Nov. 151
It Pays to Organize. Gayden Derickson....Nov. 183

J

Joints, Holding High-Pressure....May 189

K

Keep Your Motor Running. Robert J. Kolar....Oct. 172
Know Your Motor Starting Problems. Lee B. Eddy....Feb. 117

L

Law, Queer Quirks of the....Aug. 228
Lead Linings, How to Maintain and Inspect....Nov. 191
Licensing Your Process. Robert S. Aries....Feb. 147
LIGHT HYDROCARBONS
Do You Test Heavy Hydrocarbons in Gas?....April 160
Light Hydrocarbon Recovery....Sept. 304
Make Petrochemicals from Air and LPG....July 179
New Avenue for Capital . . . Oxidation of LPG....Dec. 172
Propane Market—What You Should Know....April 163
P-V-T for Liquid Butane....Nov. 190
Texas Gas Recovers More LPG....May 194
Linings, How to Maintain and Inspect Lead....Nov. 191
Liquid-Phase Isomerization....Sept. 255
Look at Synthetic Rubber Raw Materials.
John T. Cox, Jr., and W. Whitney Weinrich....Dec. 164
Look Again at the Synthetic Rubber Industry.
J. D. D'Ianni....Dec. 164
Look Carefully at Acrolein. Peter W. Sherwood....Dec. 151
Low Cost Water Effluent Separator. G. F. Ulirich
and J. E. Miller....March 211
Low Pressure Coking....Sept. 240
LPG in a Gas Sand? Store....Oct. 145
LPG, Make Petrochemicals from Air and....July 179
LPG, Texas Gas Recovers More....May 194
Lube Oil Additives—A Big Business. R. S. Aries
and A. P. Sachs....May 235

M

Maintenance Needs Engineers. L. J. Cormack....Jan. 120
MAINTENANCE
Accounting Is an Effective Maintenance Tool....Jan. 229
Compressor Trouble-Shooting....Nov. 149
Controlled Corrosion Cuts Cost....Sept. 319
Exchanger Preventive Maintenance Pays....Jan. 111
Here's How Bahrain Is Maintained....Jan. 133
How Automation Affects Maintenance Cost....May 213
How Effective Is Your Maintenance Dollar? (Part 1)...Jan. 104
How Effective Is Your Maintenance Dollar? (Part 2)...Feb. 135
How Effective Is Your Maintenance Dollar? (Part 3)
A. N. Smith....March 225
How to Maintain and Inspect Lead Linings....Nov. 191
How Maintenance Costs Can Be Controlled....March 221
How to Measure Maintenance Results....May 159
How to Reduce Compressor Downtime....Jan. 129
Installation, Operation and Maintenance of
Reciprocating Compressors....Nov. 137
It Pays to Organize....Nov. 183
Keep Your Motor Running....Oct. 172
Maintenance Needs Engineers....Jan. 120
Operations-Maintenance Coordination....Jan. 241
Planned Refinery Maintenance....Jan. 115
Planning Pays in Turbine Maintenance....Jan. 140
Preventive Maintenance in Action....May 154
Preventive Maintenance of Pumps....Jan. 121
Preventive Maintenance—Power Relays,
Circuit Breakers....Jan. 144
You Can Cut Blower Maintenance Cost....Jan. 136
Make High Octane Alky for Motor Fuel....July 192
Make Petrochemicals from Air and LPG. R. L. Mitchell...July 179
Management's "Forgotten Men." Joseph H. Trickett....July 262
Mass Spectrometer Monitoring. Ralph W. Burhans
and Warren Jackson, Jr....March 179
Mechanical Design of Reciprocating Compressors.
T. O. Kuivinen....Nov. 124
Mercapsol....Sept. 293
Metals Affect Distillate Stability. E. T. Ming
and L. L. Bott....April 192
Mitigating Gasoline Plant Corrosion. D. R. Fincher....March 218
M-O-C for Hydrogen. H. B. Morton....March 164
Models Pay Out, Do....Nov. 161
Mold Your Own Leaders. W. L. Linton....Feb. 205
Moments, Easier Solution of Continuous Beam....Oct. 169
Monitors Developed for Reforming and
Dewaxing, Continuous....Oct. 133
More Ammonia with Least Investment. W. E. Dunwoody..Dec. 169
More Cat Cracking Feed....Nov. 160
Motor, How to Select the Right....Oct. 159
Motor Running, Keep Your....Oct. 172
Motor Starting Problems, Know Your....Feb. 117
Motors Necessary, Are Explosion-Proof....Nov. 180

N

National Diesel Fuel Survey—1955....March 196
NATURAL GAS (*See* LIGHT HYDROCARBONS)
NATURAL GASOLINE (*See* GASOLINE)
Need Craft Apprentices? Try Personnel Tests.
Robert E. Chandler....Dec. 266
Need Hydrogen Compressibility Fast? W. F. Hoot....March 150
Need More Data on Hydrogen Sulfide. Dwight S. Hoffman
and James H. Weber....March 213
New Avenue for Capital . . . Oxidation of LPG.
Ronald E. Meyer....Dec. 172
New Data for Making Petrochemicals. H. R. Linden
and J. M. Reid....June 189
New Developments in Antiknock Scales. T. B. Rendel....July 170

New Look at Free World Expansion....April 266
New Method for Pipe Stresses (Part 3). K. Hao Hsiao....Feb. 153
New Method for Vapor Pressure. J. C. Winfrey....Nov. 205
New Process for Removing Reformer Feed Stock Sulfur. R. J. Phillips....Nov. 202
New Raw Material for Coke and Gasoline....Aug. 153
New Refinery Trades Coke for Power. William C. Cauthen....Aug. 141
New Separation Tool—Low Temperature. Clyde McKinley....Dec. 201
New Tests on Castables. C. M. Vogrin and Heinrich Heep....Feb. 153
New Way to Clean Up Fuels. P. J. McGuire and H. A. Price....Feb. 125
New Yugoslavian Refinery Uses Combination Approach. F. Sager....Sept. 330
Newest Olefin Polymer—Polybutene. A. R. Orr and Dewey Marks....Dec. 185
Nitrogen Compounds from Petroleum. Lewis F. Hatch....Aug. 147
Nomograms . . . Make Your Own (Part 3). Francis W. Winn....Feb. 121
Nomograms—Make Your Own (Part 4). Francis W. Winn....March 171
Nomograph for Combustion Calculations. L. A. Mekler and E. E. Ungar....June 157
Non-Union Employes, Open the Door to....Oct. 240
Now 100 Octane from Natural. G. Richard Worrell....April 138
NPSH for Proportioning Pumps, Figure....June 161

O

Octanes
Fuel Injection Changes Emphasis....July 145
Higher Octanes or Not....July 137
Turbo Autos for the Future....July 138
Ultraform to Get 100 Octane, Clear....May 171
Office Work, Streamline Your....Sept. 402
Open the Door to Non-Union Employes? William S. Wilcox....Oct. 240
Operations-Maintenance Coordination. Harry E. Kinsella....Jan. 241
Operations Research Aids the Refiner, How....Dec. 126
Operations Research, Refining Can Use....Feb. 103
Operations Research, This Is....Feb. 100
Oxidation of LPG, New Avenue for Capital....Dec. 172
OXO Reaction Data, Here are Complete....Dec. 197

P

Packed Columns, Easy Way to Design....June 187
Pemex Recovers Gasoline at Reynosa....April 206
Penex....Sept. 256
Penex and Platforming Team Up. D. H. Belden....Oct. 149
Pentaerythritol. Here's the Complete Story on this Petrochemical....Nov. 171
Pentafining....Sept. 257
Performance Characteristics of Reciprocating Compressors. Howard M. Boteler....Nov. 129
Peroxide, First Complete Story on Hydrogen....March 197
Petrochemicals in Canada. A. W. Hutchison and R. G. Stevens....Jan. 161
Petrochemicals in Synthetic Fibers. Thomas C. Ponder and John J. McKetta....Feb. 109
Petrochemicals
Don't Forget Markets in Plant Design....Dec. 187
Equilibrium Data on Ammonia....Oct. 163
Fortier Plant of American Cyanamid....March 167
Growing Fast—Butadiene Material of the Future....Dec. 157
Here Are Complete OXO Reaction Data....Dec. 197
Here's the Complete Story on this Petrochemical—Pentaerythritol....Nov. 171
Here's the Outlook for Syndets....Dec. 139
Look Again at the Synthetic Rubber Industry....Dec. 164
Look at Synthetic Rubber Raw Materials....Dec. 138
Look Carefully at Acrolein....Dec. 151
Make Petrochemicals from Air and LPG....July 179
More Ammonia with Least Investment....Dec. 169
New Avenue for Capital . . . Oxidation of LPG....Dec. 172
New Data for Making Petrochemicals....June 189
Newest Olefin Polymer—Polybutene....Dec. 185
Nitrogen Compounds from Petroleum....Aug. 147
Petrochemicals from Ammonia. Lewis F. Hatch....Dec. 146
Petrochemicals in Canada....Jan. 161
Petrochemicals in Synthetic Fibers....Feb. 109
Sulfur Compounds from Petroleum....Feb. 138
What's Ahead for Petrochemicals During 1957....Dec. 132
Which Polyethylene Process....Dec. 191
Perco HF Alkylation....Sept. 250
Percolation Filtration....Sept. 294
Petrofina Expands Refining Operations on Three Continents....Nov. 256
Phenol Extraction....Sept. 265
Phillips Gears Operations for Wide Diversification....Sept. 194
Phosphate Desulfurization....Sept. 295
Physical Properties
Equilibrium Data on Ammonia....Oct. 163
Find Absolute Viscosity by Nomograph....Nov. 169
New Method for Vapor Pressure....Nov. 205
P-V-T for Liquid Butane....Nov. 190
Pick Off Viscosity. W. W. Akers and R. A. McAllen....March 153
Pilot Plant Data, How to Scale Up....June 129
Pilot Plant, When to Use a....June 126
Pin Pricks from Within. William S. Wilcox....March 274
Piping
New Method for Pipe Stresses (Part 3)....Feb. 153
Rapid Design of Pipe Supports....April 195
Which Steel for High Temperature Piping....Nov. 185
Place to Grow. William E. Bright, Jr....May 268
Plan and Control Capital Expenditures, How to....Aug. 200
Planned Refinery Maintenance. W. G. Elgie....Jan. 115
Planning Pays in Turbine Maintenance. H. A. McGill and J. M. Zylks....Jan. 140
Plant for Less Money, To Get More....Oct. 108
Platforming....Sept. 222
Platforming in One Unit, Unifining....May 216
Platforming Team Up, Penex and....Oct. 149
Pollution Help, Here's Air....Aug. 156
Polybutene, Newest Olefin Polymer....Dec. 185
Polyco Catalytic Polymerization....Sept. 259
Polyethylene Process, Which....Dec. 191
Polymerization Processes....Sept. 247
Polyols, What's the Outlook for....Oct. 141
Power Failures, How to Avoid....Jan. 108
Power, New Refinery Trades Coke for....Aug. 141
Power and Utilities
Compare Engine Fuel Costs....Jan. 164
Cooling Water Filters Save Money....April 135
Designing an Electric Power System....March 201
How to Avoid Power Failures....Jan. 108
Preventive Maintenance—Power Relays, Circuit Breakers....Jan. 144
Simplify Boiler Water Treatment....Nov. 193
Powerforming....Sept. 213
Preventive Maintenance of Process Pumps. William M. Wise....Jan. 131
Preventive Maintenance—Power Relays, Circuit Breakers. Charles T. Fisk....Jan. 144
Preventive Maintenance in Action. C. C. Carmine....May 154
Propane Deasphalting....Sept. 266
Propane Decarbonizing....Sept. 267
Propane Dewaxing....Sept. 268
Propane Fractionation....Sept. 269
Propane Market—What You Should Know. R. W. Linehan....April 163
Pumps
Check This Plant's Pumping System....April 98
Figure NPSH for Proportioning Pumps....June 161
How to Select and Install Pump Seals....March 207
How to Select the Right Pump Motor....Oct. 159
How to Select Centrifugal Pumps....Sept. 241
Preventive Maintenance of Process Pumps....Jan. 131
Planning Pays in Turbine Maintenance....Jan. 140
Steam Pump Trouble Shooting....June 140
P-V-T for Liquid Butane. Dale S. Davis....Nov. 190

Q

Queer Quirks of the Law....Aug. 228

R

Radioactivity, Take Stock of....May 201
Rapid Design of Pipe Supports. R. H. Karol....April 195
Recycle Hydrogenated Shale Oil Crude. R. L. Crecelius, E. O. Knidachy, E. R. White, P. L. Cottingham and W. I. R. Murphy....June 171
Refined Products Outlook for 1957....Oct. 130
Refineries: Domestic
Baytown Virtually Rebuilt....June 122
$560 Million Postwar Expansion Program....Jan. 100
How a Small Refinery Grew....Oct. 104
New Refinery Trades Coke for Power....Aug. 141
Phillips Gears Operations for Wide Diversification....Sept. 194
Socony Mobil's Greatest Expansion Period....Feb. 98
Standard-Vacuum's Postwar Construction....March 270
Two Jersey Affiliates Build to Meet Postwar Demands....July 134
Refineries: Foreign
From Chaos to Europe's Leading Refiner....Dec. 280
Here's How Bahrain Is Maintained....Jan. 132
New Yugoslavian Refinery Uses Combination Approach....Sept. 330
Pemex Recovers Gasoline at Reynosa....April 206
Petrochemicals in Canada....Jan. 161
Petrofina Expands Refining Operations on Three Continents....Nov. 256
This Refinery Went Underground....May 225
Refining Behind the Iron Curtain....Sept. 417
Refiner's Reaction to RP-500. F. C. Somers....June 202
Refinery Integrates Three Hydrofiners. A. Brandon and L. W. Zahnstecher....Oct. 166
Refining Can Use Operations Research. Arthur A. Brown....Feb. 103
Refining Forecast: $20.1 Billion Outlay by 1965....Feb. 153
Reforming
Aramco's Fluid Hydroformer Produces 92.5 Clear Octane....Aug. 157
Continuous Monitors for Reforming and Dewaxing....Oct. 133
Hydrogen Sulfide Corrosion in Sovaformers....Aug. 165
New Process for Removing Reformer Feed Stock Sulfur....Nov. 202
Penex and Platforming Team Up....Oct. 149
Processes....Sept. 205
Rexforming Unit Makes 104 Octane....Oct. 138
Unifining-Platforming in One Unit....May 216
Ultraform to Get 100 Octane, Clear....May 171
Relays, Circuit Breakers, Preventive Maintenance—Power. Jan. 144
Research Committee Reports. L. C. Kemp, Jr....May 178
Research Cost, Estimating....June 134
Retirement, 'Blueprint' for....Feb. 202
Retort Oil Shale for Chemicals. H. M. Thorne....July 155
Revamping a Gasoline Plant. M. L. Arnold and R. J. Hull....April 148
Revitalize Your Tower. J. M. Whitesell and Anthony Durando....March 186
Rexforming....Sept. 223
Rexforming Unit Makes 104 Octane....Oct. 138
Rigging Sequence Is Planned, How a....March 227
RP-500, A Contractor's Reaction to....May 151
RP-500, Refiner's Reaction to....June 202
Ropes Plant . . . Low-Volume, Rich Gas With a Long Life. F. H. Lacy, Jr., and G. B. Evans....June 147

S

Safety
Accident Control Through Supervision....July 254
Contractor's Reaction to RP-500....May 151
Find the Reasons for Unsafe Acts....Sept. 428
Five Steps to Safety....June 238
Five Ways to Safety....Jan. 256
Refiner's Reaction to RP-500....June 202
Research Committee Reports....May 178
Showmanship Can Prevent Accidents....Feb. 212
What Causes Accidents?....Aug. 212
Sand, Store LPG in a Gas....Oct. 145
Save Tanks With Cathodic Protection. Wayne A. Johnson....March 216
SBK Catalytic Reforming....Sept. 214
Scale Up Pilo. Plant Data, How to....June 129
Scale Up, What to Avoid in....June 126
Seals, How to Select and Install Pump....March 207
Separator, Low Cost Water Effluent....March 211
Shale for Chemicals, Retort Oil....July 155
Shale Oil Compete With Crude, When Will....July 153
Shale Oil, Union Oil of California Bets Heavily on....July 161
Shale Oil Crude, Recycle Hydrogenated....June 171

## SUBJECT INDEX *continued*


Shorten Heat Transfer Problems. W. W. Akers and O. A. Sampson....March 152
Showmanship Can Prevent Accidents. Paul Lockwood....Feb. 212
Simplify Boiler Water Treatment. Maxey Brooke....Nov. 193
Simplify Gas Cooling Design. G. H. P. Bras....March 191
Small Refinery Grew, How....Oct. 104
Snap-On Insulation....Feb. 112
Socony Mobil's Greatest Expansion Period....Feb. 98
Solid Phosphoric Acid Condensation....Sept. 260
Solutizer Process....Sept. 296
Solvent Dewaxing....Sept. 271
Solvent Refining Processes....Sept. 261
$SO_2$ Extraction....Sept. 270
Sovaformers, Hydrogen Sulfide Corrosion in....Aug. 165
Stability, Metals Affect Distillate....April 192
Standard-Vacuum's Postwar Construction....March 270
Steam Pump Trouble Shooting....June 140
Steam Trace Refinery Piping, How to....July 187
Steel for High Temperature Piping, Which....Nov. 185
Store LPG in a Gas Sand? Homer C. Givens....Oct. 145
Streamline Your Office Work. William E. Sexton....Sept. 402
Stroud Plant . . . Portability With Easy Construction. Otha H. Grimes....June 152
Suggestion Systems, Why....Sept. 410
Sulfur, New Process for Removing Reformer Feed Stock..Nov. 202
Sulfur Plants, How to Stop Corrosion in....July 183
Sulphur Compounds from Petroleum. Lewis F. Hatch....Feb. 138
Sulfuric Acid Alkylation....Sept. 251
Superfractionator Design Consideration. S. T. Kiguchi and R. L. Ridgway....Dec. 179
SWEETENING (*See* TREATING)
Switchgear, Esso Installs 34.5 KV Station....May 196
Syndets, Here's the Outlook for....Dec. 139
Synthetic Fuels Justified in Africa. George E. Mapstone....Oct. 159
Synthetic Rubber Industry, Look Again at the....Dec. 164
Synthetic Rubber Raw Materials, Look at....Dec. 138

T

Take Another Look at Charcoal Test. Horace R. Crawford..April 166
Take Stock of Radioactivity. E. G. Fritz....May 201
Taking Stock....Monthly Feature
TESTS (*See* ANALYSIS)
Texas Gas Recovers More LPG. Ruble L. Huff....May 194
There's a Limit to Use of Equations of State. Lawrence N. Canjar....Feb. 113
Thermal Cracking (See also Cracking)....Sept. 245
Thermal Reforming (See also Reforming)....Sept. 226
Thermodynamics for Process Evaluation. Hendrick C. Van Ness....Jan. 165
Thermofor Catalytic Reforming....Sept. 216
These Get the Job Done for Me....May 136
Think Before You Write. W. B. Etheridge....May 294
This Is Operations Research. Merrill M. Flood....Feb. 100
This New Plant Is Semi-Automatic. Layton Kitterman and Charles B. Barry....April 180
This Plant Is Going Modern. R. J. Brosamer and P. E. Goth, Jr....April 152
This Refinery Went Underground. Herbert C. Fries....May 225
To Get More Plant for Less Money. Thomas C. Ponder....Oct. 106
Trace Analysis Catches Up....May 184
TREATING
Control the Slurry in Copper Sweetening....June 186
Gas Conditioning Today (Part 2)....Feb. 133
Hydrazine Cuts Water Treating Costs....Dec. 208
New Process for Removing Reformer Feed Stock Sulfur..Nov. 202
New Ways to Clean Up Fuels....Feb. 125
Processes....Sept. 274
Refinery Integrates Three Hydrofiners....Oct. 166
What Hydrogen Treating Can Do....Sept. 306
What Unifining Can Do for You....July 193
Trickle Hydrodesulfurization....Sept. 297
Tubes Worth, What Are Heater....Aug. 133
Turbine Maintenance, Planning Pays in....Jan. 140
Turbo Autos for the Future. Lamont Eltinge....July 138
Two Jersey Affiliates Build to Meet Postwar Demands....July 134

U

Underground Storage—Store LPG in a Gas Sand?....Oct. 145
Ultraform to Get 100 Octane, Clear. Philip C. White, W. F. Johnston, W. J. Montgomery....May 171
Ultraforming....Sept. 218
Unifining Can Do for You, What....July 193
Unifining....Sept. 293
Unifining-Platforming in One Unit. C. F. Gerald....May 216
Union Flares Blowdown Without Smoke. J. R. Hannaman and A. J. Etingen....Feb. 143
Union Oil of California Bets Heavily on Shale Oil....July 161
Unisol Mercaptan Extraction....Sept. 299
Unsafe Acts, Find the Reasons for....Sept. 428
UTILITIES (*See* POWER AND UTILITIES)
Up-to-Date on Plant Instrumentation. Blair J. Willard..April 170
Use Computers for Refining Problems. Jack Sherman....May 139

V

Vapor-Phase Chromatography. Walter J. Podbielniak and Seaton T. Preston....April 215
Vapor-Phase Hydrodesulfurization....Sept. 300
Vapor Pressure, New Method for....Nov. 205
Vapor Yields on Flashing. J. A. Grosberg and George E. Mapstone....April 208
Vessels, How to Specify High Pressure....Oct. 108
Viscosity by Nomograph, Find Absolute....Nov. 169
Viscosity, Pick Off....March 153

W

Want Equipment Costs for Estimates? O. T. Zimmerman and Irvin Lavine....Aug. 116
Want Refinery Costs Quickly? William E. Tucker....Aug. 100
WASTE DISPOSAL
Check Effluent With Bioassay....June 197
How New Is the Disposal Problem?....May 181
Union Flares Blowdown Without Smoke....Feb. 143
WATER TREATING (*See* POWER & UTILITIES)
Wax Fractionation....Sept. 272
Wax Manufacturing....Sept. 273
What Are Heater Tubes Worth? R. B. Smith and R. R. Edison....Aug. 133
What Causes Accidents?....Aug. 212
What Causes Hydrogen Attack. Gordon R. King....March 155
What Happens in Hydrogen-Hydrogen Sulfide Corrosion. E. B. Backensto, R. D. Drew and C. C. Stapleford....Jan. 147
What Hydrogen Does to Metals. H. C. Van Ness....March 160
What Hydrogen Treating Can Do. Herbert Kay....Sept. 306
What to Avoid in Scale Up. D. P. Thornton, Jr....June 136
What Makes an Employe Tick? E. L. K. Frost....Oct. 220
What Petrochemical Plants Cost. Robert D. Hill....Aug. 106
What Price Hydrogen? Hugh Fairclough....Sept. 333
What Unifining Can Do for You. Harry F. Poll....July 193
What Will Gasoline Be Like in 1960? J. G. Moxey, Jr....May 230
What's Ahead for Petrochemicals During 1957. Raphael Katzen....Dec. 132
What's Happening to Gas Contracts? John O. Sue....April 151
What's the Lower Limit for Gas Processing? H. William Prengle, Jr., A. E. Dukler, Joseph R. Crump and Berry E. Norris....April 141
What's the Outlook for Polyols? J. W. Everson....Oct. 141
When to Use a Pilot Plant. John W. Payne....June 126
When Will Shale Oil Compete With Crude?....July 153
Where Do We Go from 65? Allan J. Fleming and C. A. D'Alonzo....Oct. 229
Which Polyethylene Process. R. L. Thoasson, John J. McKetta and Thomas C. Ponder....Dec. 191
Which Steel for High Temperature Piping. E. A. Sticha....Nov. 185
Why Human Relations? Harry L. Kidd....Aug. 98
Why Suggestion Systems? William S. Wilcox....Sept. 410
Will Atomic Energy Replace Oil? Robert E. Wilson....Nov. 118
Will Oil Prices Go Up?....June 176
World Demand to Increase One-Third in Five Years....Sept. 426

Y

You Can Cut Blower Maintenance Cost. J. L. Hylton....Jan. 136
Yugoslavian Refinery Uses Combination Approach, New..Sept. 330


## *And these departments monthly . . .*

Quick Look
Mail Box
Quick Look at Industry
Look Box
How to Do It
Who's Building
Construction Boxscore (Quarterly)
What's Happening
Men in the Industry
Meetings Calendar
Suppliers Notes
Reviewing New Books
Classified Advertising
New Equipment
New Literature
Index to Advertisers
Readers' Service Cards

# Reviewing New Books . . .

**Petroleum Facts and Figures** is designed to be the most convenient source of information on the petroleum industry. It is now in its twelfth edition and contains facts on production, refining, transportation, and marketing. Material is given on other less common subjects which include prices, taxation, fires, safety, and labor.

Together with the ninth edition (1950), the present volume provides a statistical history of the oil industry dating from the earliest years for which comparable information is available. Where no new information is available, tabulations appearing in the Ninth Edition have not been repeated. In all other instances, however, this Twelfth Edition supplements and brings up to date the earlier record. Statistical tables on marketing and data on petrochemicals appear, while coverage of offshore operations and sales of lubricants have been widely extended.

(American Petroleum Institute, 50 West 50th Street, New York 20, N. Y., 390 pages.)

**Smoleys Tables Handbooks,** are new revised and enlarged editions (7 inches x 4¾ inches page size) of time saving manuals for civil and structural engineers, designers, draftsmen, architects, and students.

As in the past they comprise six volumes; the four single volumes: 1. *Smoley's Logarithms and Squares;* 2. *Smoley's Logarithmic Trigonometric Tables;* 3. *Smoley's Parallel Tables of Slopes and Rises;* and 4. *Smoley's Segmental Functions.* The next two volumes are made up of *Smoley's Three Combined Tables* which include numbers 1, 2, and 3 (above) and *Smoley's Four Combined Tables* which includes all of the four single books.

The prices and number of pages of the books are listed below:

1. Parallel Tables of Logarithms and Squares (688 pages) $6.00.
2. Five Decimal Logarithmic Trigonometric Tables (200 pages) $1.50.
3. Parallel Tables of Slopes and Rises (532 pages) $6.00.
4. Segmental Functions (436 pages) $5.00.
5. Three Combined Tables (Above 3 books in 1) (1,124 pages) $10.00.
6. Four Combined Tables (1, 2, 3, 4, in 1 volume) (1,424 pages) $12.00.

(C. K. Smoley & Sons, Inc., P. O. Box 14, Chautauqua, N. Y.)

**Fisher/Tag Manual for Inspectors of Petroleum,** is much handier than the standard encyclopedia of official petroleum tests which is, of course, the 954-page *ASTM Standards on Petroleum Products and Lubricants* and its companion *ASTM-IP Petroleum Measurement Tables.* But 5 pounds of books aren't very handy in the field. That's where this manual comes in.

The 37 test methods most used by field men have been edited down to their essentials. Added were the most important gravity and viscosity tables, and a number of other reference and conversion tables. In the 1956 edition, the copper corrosion test (ASTM D-130) is completely revised to incorporate the new ASTM specifications.

(Fisher Scientific Co., 390 Fisher Bldg., Pittsburgh 19, Pa., 200 pages, $1.75.)

**Supervision of Scientific and Engineering Personnel,** compiled by **John T. Lloyd,** and **Robert D. Gray,** is a comprehensive workbook which was derived from a number of conferences and meetings sponsored by the Industrial Relations Section of the California Institute of Technology. In 1953, the Industrial Relations Section held its first summer conference on "Supervision of Engineering, Scientific and Technical Employes." As a result of this program, a series of ten evening meetings were held on the same subject between January and March, 1954. Again in the summer of 1954 a full time conference was held and this was followed in the spring of 1955 by two series of evening meetings. During 1955-56 other groups discussed preliminary drafts of this summary. This outline, therefore, is a composite of the subjects discussed and the opinions expressed in the meetings. Some information was obtained from the literature available in the Industrial Relations Library and other libraries of the California Institute of Technology. Most of the material, however, has been drawn from the discussions and outlines of the conference leaders.

Some of the subjects outlined are: "Building and Maintaining a Good Technical Team;" "Appraisal of Performance;" "Policies for Salary Administration;" "Unionization of Professional Employes;" and "What Professional Workers Expect of their Supervisors."

(Bookstore, California Institute of Technology, Pasadena, Cal., 82 pages, price ranges from $8.75 for one copy to $3.50 each for 1000 or more copies.)

**Commercial Waxes,** edited by **H. Bennett** is an up-to-date, enlarged and revised edition of a successful book.

Much additional information has been included on natural and synthetic waxes, wax blends and wax-resin compositions. A substantial part of the data has not been published before and the balance has been compiled from many different technical publications.

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Over 160 tables list important data on the physical and chemical properties of waxes, such as melting point, specific gravity, hardness, purity, fracture and form, moldability, adhesiveness, solubility, penetration, surface tension, compatibility, waterproofness, acid, iodine, saponification and ratio numbers, etc.

More than 60 graphs show the relationships of physical properties, effects of adhesives, etc.

It includes a symposium with contributions by many experts and leading manufacturers. Its wax formulary embraces hundreds of formulas from every important branch of the chemical industries in which various waxes are used as raw materials or modifying agents.

The glossary of terms and an efficient index will save time and effort to busy technical workers.

(Chemical Publishing Co., 212 Fifth Ave., New York 10, N. Y., 698 pages, $15.00.)

**Methods For Reducing The Effect Of Barometric Pressure In Measurement Of Octane Number,** an ASTM special technical publication in which results are presented in the form of tables of empirically determined operating conditions that will lead to substantially the same octane number when operated at any atmospheric pressure between 21.0 and 30.5 in. of mercury absolute.

The paper is of particular interest to those concerned with the combustion of fuels in knock test engines. Recent improvements in the ASTM methods for engine rating of fuels were made on the basis of data presented in this book.

(American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa., 28 pages, $1.50.)

**AEC Research Reports Price List No. 26,** is a new free price list of Atomic Energy Commission unclassified research reports for sale by the Office of Technical Services, U. S. Department of Commerce, and is now available from OTS on request.

This cumulative listing of the more than 3,000 AEC reports in the OTS collection contains 1,034 items acquired since January 1, 1956. Price lists are issued semi-annually, and the next list will be available in February, 1957.

(OTS, United States Department of Commerce, Washington 25, D. C., Free.)

**Effects of Mineral Additives on the Durability of Coating-Grade Roofing Asphalts,** by **Sidney H. Greenfeld,** National Bureau of Standards Building Material and Structures Report 147. This publication summarizes a study made recently at the Bureau on weathering resistance of asphalts with mineral additives. Combinations of asphalts and additives were investigated to find how durability varied with additive concentration; film thickness; particle size, shape, and distribution; natural variations in similiar minerals from different sources; and thoroughness of mixing.

An important part of the investigation dealt with weathering resistance. Because actual service evaluation takes up to 20 years, accelerated weathering tests that can be made in the laboratory were used. The asphalts investigated were obtained from three widely different crudes and are typical of asphalts used in the manufacture of shingles.

(U. S. Government Printing Office, Washington 25, D. C., 14 pages, 20 cents.)

(Note: Foreign remittance must be in U. S. exchange and should include an additional one-third of the publication price to cover mailing costs.)

**Collection of Papers Presented at the Colloquim in Statistical Design of Laboratory Experiments,** Navy Ordnance Laboratory, June, 1955, is a collection of Navy-sponsored lectures on the philosophy and practical use of statistics in research and design have been published in a single volume and made available to the public.

The lectures were presented by civilian statisticians during a colloquim conducted at the Naval Ordnance Laboratory in 1954. They contain a series of viewpoints useful to the engineer or scientist concerned with designing experiments and

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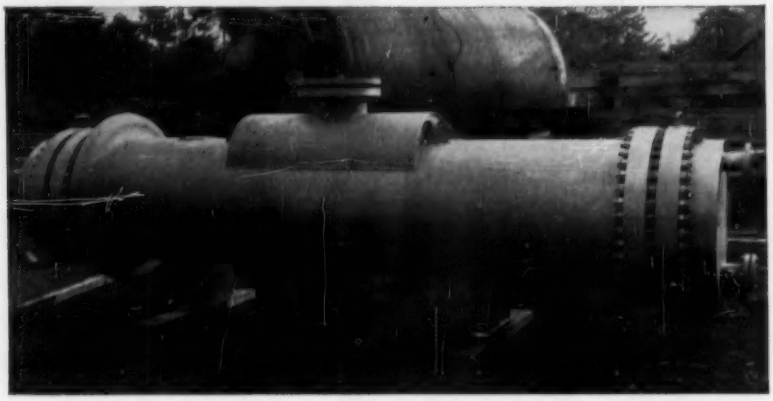

Inconel and stainless heat exchanger built for Barrett Division, Allied Chemical & Dye Corporation. Shell Diameter: 30″. Tube Length: 12′ 0″. Tubes: 1″ O.D. x 14 ga. Tube Sheet Thickness: 2″. Materials: Inconel shell, tubes, tube sheets. Stainless steel heads, Type 316L.

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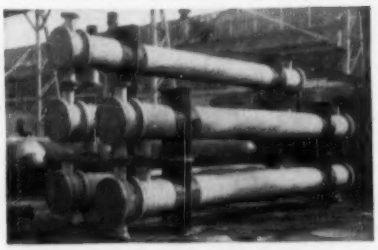

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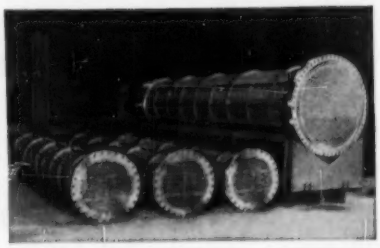

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## New Books . . .

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(OTS, U. S. Department of Commerce, Washington 25, D. C., volume PB121181, 102 pages, $2.75.)

**ASTM Standards on Engine Anti-freezes,** is a compilation of all ASTM methods of tests pertaining to engine anti-freezes; this compact handbook containing 11 standards—9 test methods and 2 specifications should be of considerable interest to both producers and consumers of engine anti-freezes.

Prepared under the sponsorship of Committee D-15 on Engine Anti-Freezes, the compilation contains in addition to the test methods and specifications an Appendix. Included in the Appendix are Notes on Significance and Interpretation of the Glassware Corrosion Test and the Personnel of Committee D-15.

The contents include: methods for sampling, determining freezing points, physical testing, chemical testing, and in addition, specifications for a hydrometer-thermometer field tester and thermometers.

(American Society for Testing Materials Headquarters, 1916 Race Street, Philadelphia 3, Pa., 52 pages, $1.50.)

**Modern Instruments in Chemical Analysis,** by **Frank M. Biffen,** Research Specialist, Johns-Manville Research Center; and **William Seaman,** Head of Analytical Research, Bound Brook Laboratories, Research Division, American Cyanamid Company.

This new book explains modern chemical instruments as tools which help the chemist achieve maximum accuracy and economy in his everyday analytical work. From it he will get a clear understanding of how the newer instruments work, and the results he can obtain from them.

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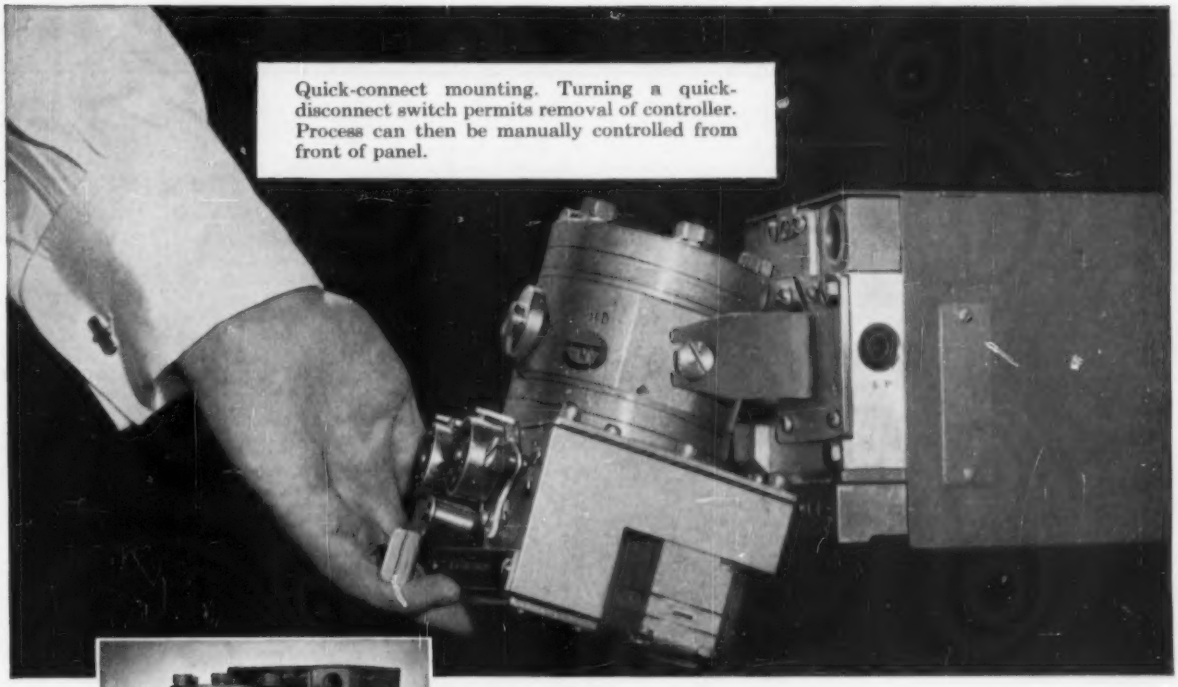
This book simplifies the great mass of material on today's more complex chemical instrumentation, without departing from true scientific principles. Its approach is essentially non-mathematical, and it contains a minimum of theory.

(McGraw-Hill Book Co., Inc., 330 W. 42nd St., New York 36, N. Y., 333 pages, $7.50.)



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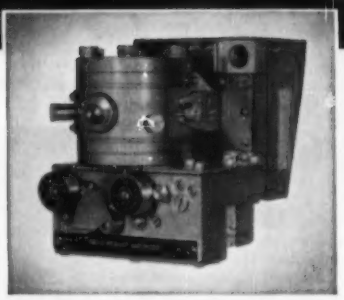

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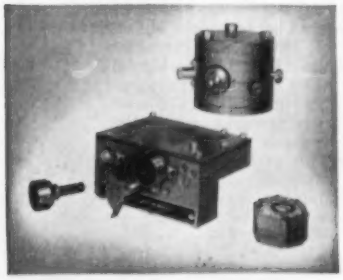

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# What Suppliers Are Doing . . .

Reimer

**R. E. Reimer,** vice president, secretary and treasurer of **Dresser Industries, Inc.,** has been elected to the Dresser board of directors. Reimer, a graduate of the University of Cincinnati, has been associated with Dresser since the company first became publicly owned in 1929. He served as controller of the original Dresser company from 1929-1932, as treasurer from 1933-1943, as secretary-treasurer of Dresser Industries, Inc., from 1943-1947. He was elected a vice president of the Company in 1947.

Ludlow

**Alden R. Ludlow, Jr.** has been named director of sales for **U. S. Industrial Chemicals Co.,** division of National Distillers Products Corporation. Ludlow succeeds **Lee A. Keane** who has just retired.

Ludlow has been with U. S. I. since he graduated from Yale University in 1934, with the exception of several wartime years spent overseas with the U. S. Air Force. He has been U. S. I.'s manager of alcohol sales for the past ten years. During his long service with the chemical industry Ludlow has been a member of and taken an active part in many trade associations.

Green

**Jack L. Green,** Houston, has been appointed sales representative by the **Lunkenheimer Company** of Cincinnati, Ohio. Green succeeds **Joseph A. Birkhead,** who died last September.

A native of California, Green joins the Lunkenheimer sales staff following 13 years in sales during which time he covered the Rocky Mountain and Southwestern petroleum, power and other industries for the Republic Supply Company and the Western Oil Tool and Manufacturing Company.

Rowe

**Carl E. Rowe,** has been appointed vice president and general manager of the **Milwaukee Valve Company.** Rowe was also made a director of the firm. Rowe was previously associated with Pressco Casting and Manufacturing Company of Chesterton, Indiana as vice president in charge of manufacturing. For a time, he also headed his own firm, Carl E. Rowe and Company Incorporated, Milwaukee, Wisconsin and is widely known in foundries and allied fields as a technical and management consultant in the middle West and East.

Gleason

**Jerome S. Gleason,** Buffalo, N. Y., has been appointed territory sales manager in western New York state by the **Alloy Tube Division** of **The Carpenter Steel Company,** Union, N. J.

Gleason was formerly associated with the Electric Elevator division of Westinghouse Electric Corporation, in Jersey City, N. J., where he served in purchasing, production and sales capacities.

**John A. Carrington** has been appointed general sales manager of **The Harvill Corporation,** Los Angeles. Carrington will direct an expanded national sales program for all divisions of Harvill.

Before joining Harvill, Carrington, a Stanford graduate and long-time resident of San Marino, was president and co-owner of Hancar Merchandising Corporation, Los Angeles, and California manager of Cavendish Trading Corporation, Los Angeles, national marketing organization.

Prior to this, he was a Junior Vice President of Citizens' National Trust and Savings Bank, Los Angeles, in charge of business promotion, and for five years manager of the domestic trade division and director of public relations of the Los Angeles Chamber of Commerce.

Carrington

**William T. Durkin** has been appointed manager of **Clark Brothers'** Pittsburgh office. Durkin completed his formal training at Villanova University, graduating with a degree in mechanical engineering. Prior to his present appointment, Durkin held the position of manager of the reciprocating engineering sales department of Clarks in Olean, N. Y.

Durkin

**William Rainey** has been appointed manager of new product development for W-S Fittings Division, **H. K. Porter Company, Inc.** Rainey will be in charge of market research and new product development for the division, and will assist in correlating the efforts of the sales and engineering departments.

Prior to his present appointment, Rainey was self employed as an air conditioning engineer and contractor. He had also been associated with Orr and Sembower Company of Pennsylvania for 4 years in engineering and sales and as an engineer with American Chain and Cable Company.

Rainey

**Carl W. Ferris** has been named manager of the newly created Chicago district of the central region of **Du Pont's Petroleum Chemicals Division.** A mechanical engineering graduate of Cornell, Ferris joined Du Pont in 1947. He did test work, investigating exhaust valve burning, spark plug fouling and power losses at the company's petroleum laboratory at Deepwater Point, N. J. He was assigned to the central region in 1951 and has been an account manager working out the Chicago regional office.

Ferris

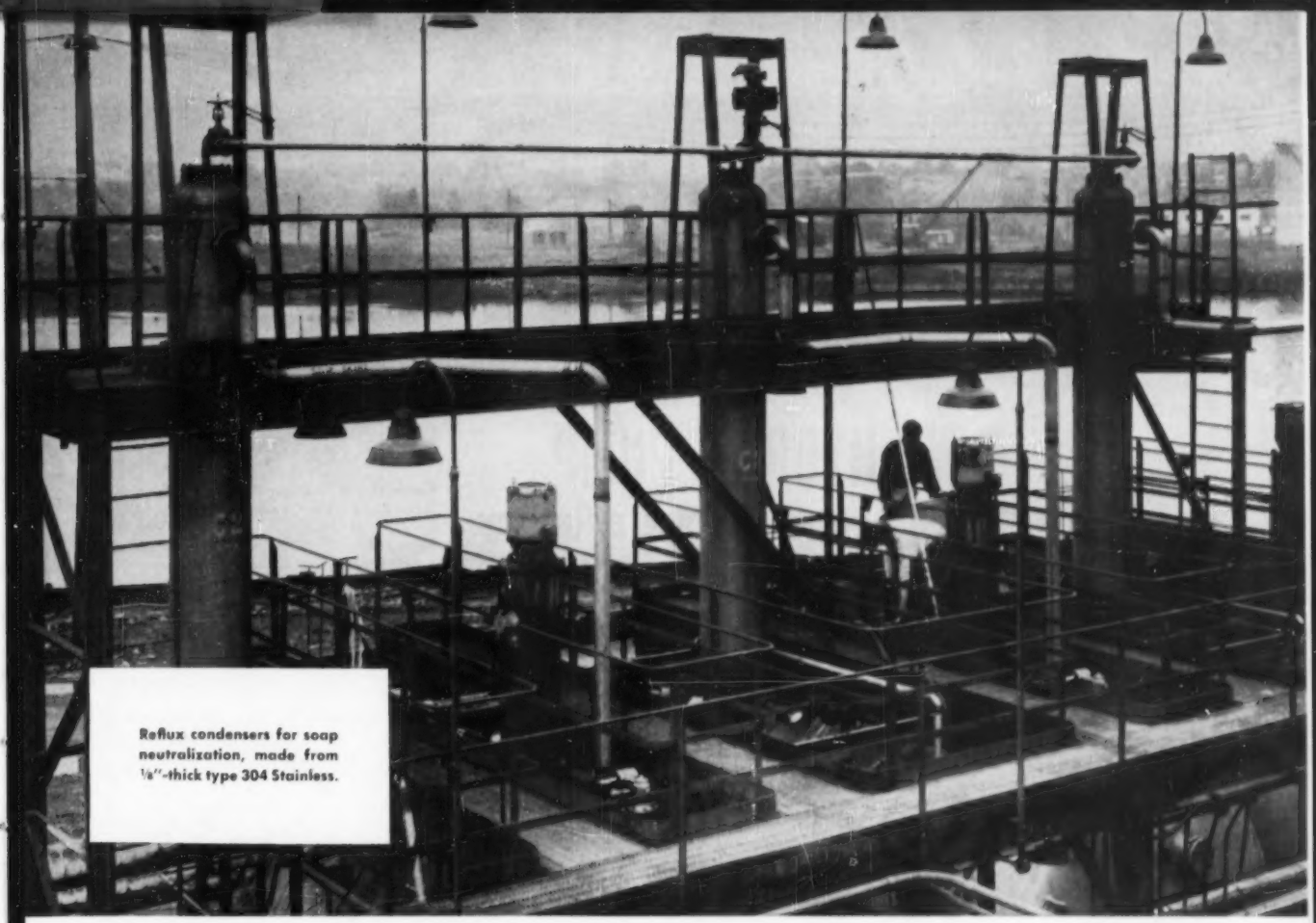
**Larry Harper, Franklin Supply Company,** has been elected executive vice president of the company.

The announcement was made by **Jene Harper, Franklin** president, following the annual board meeting held at the company's ranch in Colorado. In his new position, Harper will supervise the operation of Franklin's 22 stores and offices in the U. S. and Canada.

Harper

**Worthington Corporation** announced the election of **Wilbur R. Shook** as treasurer, Succeeding **Harold A. Bellows,** who is retiring.

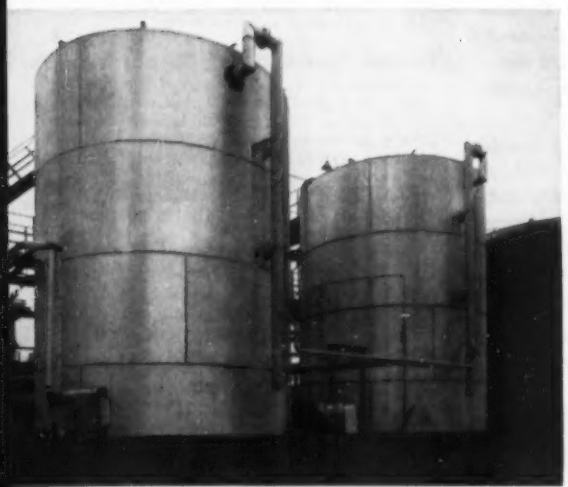
Bellows has served the company for 16 years as assistant treasurer from 1940-42



Reflux condensers for soap neutralization, made from ⅛"-thick type 304 Stainless.

# Not a Single Stainless Steel failure

## in equipment for handling finished detergents



Synthetic detergent tanks (Stainless) have been in service for four years and are still as good as new. Previous coated tanks lasted 18-24 months.

The Atlantic Refining Company's Philadelphia refinery produces detergents as one of the derivatives.

Product contamination was the big problem. They tried sprayed-on plastic and phenolic coatings, but they all failed. Since they installed Stainless Steel, there has not been a single failure in the finished product handling equipment. There has been no corrosion problem. No contamination.

Nothing can equal Stainless Steel in its combination of properties: corrosion resistance, surface smoothness and denseness, strength and hardness, easy fabrication. Think of Stainless when you plan. Think of *USS* Stainless when you buy.

UNITED STATES STEEL CORPORATION, PITTSBURGH • AMERICAN STEEL & WIRE DIVISION, CLEVELAND
COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO • NATIONAL TUBE DIVISION, PITTSBURGH
TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA.
UNITED STATES STEEL SUPPLY DIVISION, WAREHOUSE DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

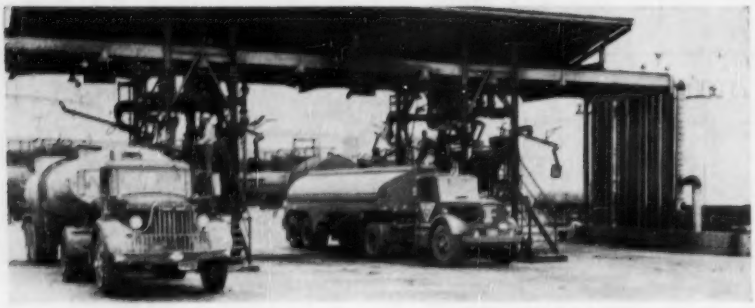
# USS STAINLESS STEEL

SHEETS • STRIP • PLATES
BARS • BILLETS

USS

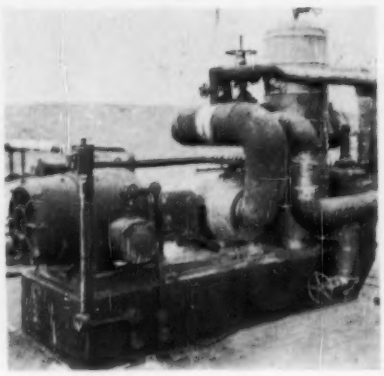
PIPE • TUBES • WIRE
SPECIAL SECTIONS

UNITED STATES STEEL



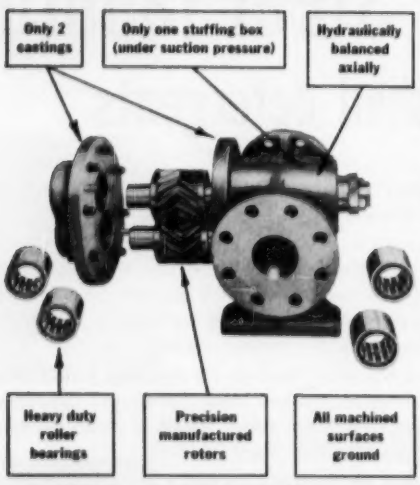
# *Sier-Bath* HYDREX® PUMP

## cuts pump cost—improves pumping efficiency at CALIFORNIA OIL COMPANY



• At the Perth Amboy, N. J. plant, this Hydrex Gear Pump transfers Bunker "C" Fuel Oil from storage tanks to trucks. Completely insulated, it pumps oil at 200°F., with 350 gpm. capacity; operates intermittently 8 hours a day, 6 days a week in winter, half that in summer. Although lower in price, the company rates the Hydrex more efficient than the gear pump it replaced. Hydrex dependability is vital, since no spare pump is at this location. Twelve other Sier-Bath pumps are giving excellent service throughout the plant.

***Sier-Bath* HYDREX PUMP**


Only 2 castings
Only one stuffing box (under suction pressure)
Hydraulically balanced axially
Heavy duty roller bearings
Precision manufactured rotors
All machined surfaces ground

The simplest heavy duty gear pump made! Use it in place of pumps costing much more . . . for handling chemical solutions, fuel oils, lube oils, hydraulic liquids, etc.

The "Hydrex" needs no costly speed reducer—can be direct-connected up to 1800 RPM. Extreme simplicity allows heavier construction, easier installation and maintenance, less downtime, longer life.

Models available to pump liquids from 32 SSU to 250,000 SSU, at 1 to 350 GPM, up to 500 PSI. Call your local Sier-Bath Pump Representative . . . write to *Sier-Bath Gear & Pump Co., Inc., 9261 Hudson Blvd., North Bergen, N. J.*

# *Sier-Bath* ROTARY PUMPS

Screw Pumps — Gearex® Pumps — Hydrex® Pumps

50th Anniversary — Mfrs. of Precision Gears, Rotary Pumps, Flexible Gear Couplings — Member A.G.M.A.

## Suppliers . . .

and treasurer since that date. He will continue as a consultant on pension and insurance matters.

Shook has been assistant secretary of Worthington since 1947 and was previously associated with the New York law firm of Chadbourne, Hunt, Jaeckel and Brown. He is a graduate of Yale University and received his law degree from Harvard University in 1936.

**Douglas H. Springer,** who has been a member of the legal department since 1952, will succeed Shook as assistant secretary. Springer is a graduate of Yale University and Columbia Law School.

**Conoflow Corporation** has appointed **The Lewis M. Crowe Company,** Atlanta, Ga., as its sales representative. The Lewis M. Crowe Company will be exclusive sales agency for ConoControls in the state of Georgia and the eastern section of Tennessee.

**Worthington Corporation,** Mason-Neilan division has appointed **Carl W. Gram, Jr.** vice president in charge of sales.

Gram graduated from Dartmouth College in 1937 and joined the sales division of The Mason-Neilan Regulator Co. He served as lieutenant in the Navy during World War II.

In 1953, Gram was named manager of the petroleum and chemical sales division, with headquarters in New York City. In this capacity he has been responsible for sale of the complete line of Mason-Neilan instruments, control valves and regulators.

**Warner Lewis Company** has appointed **Warner Lewis, Jr.,** as midwest zone manager. Prior to his new appointment, Lewis served as assistant sales manager in charge of sales in the western United States.

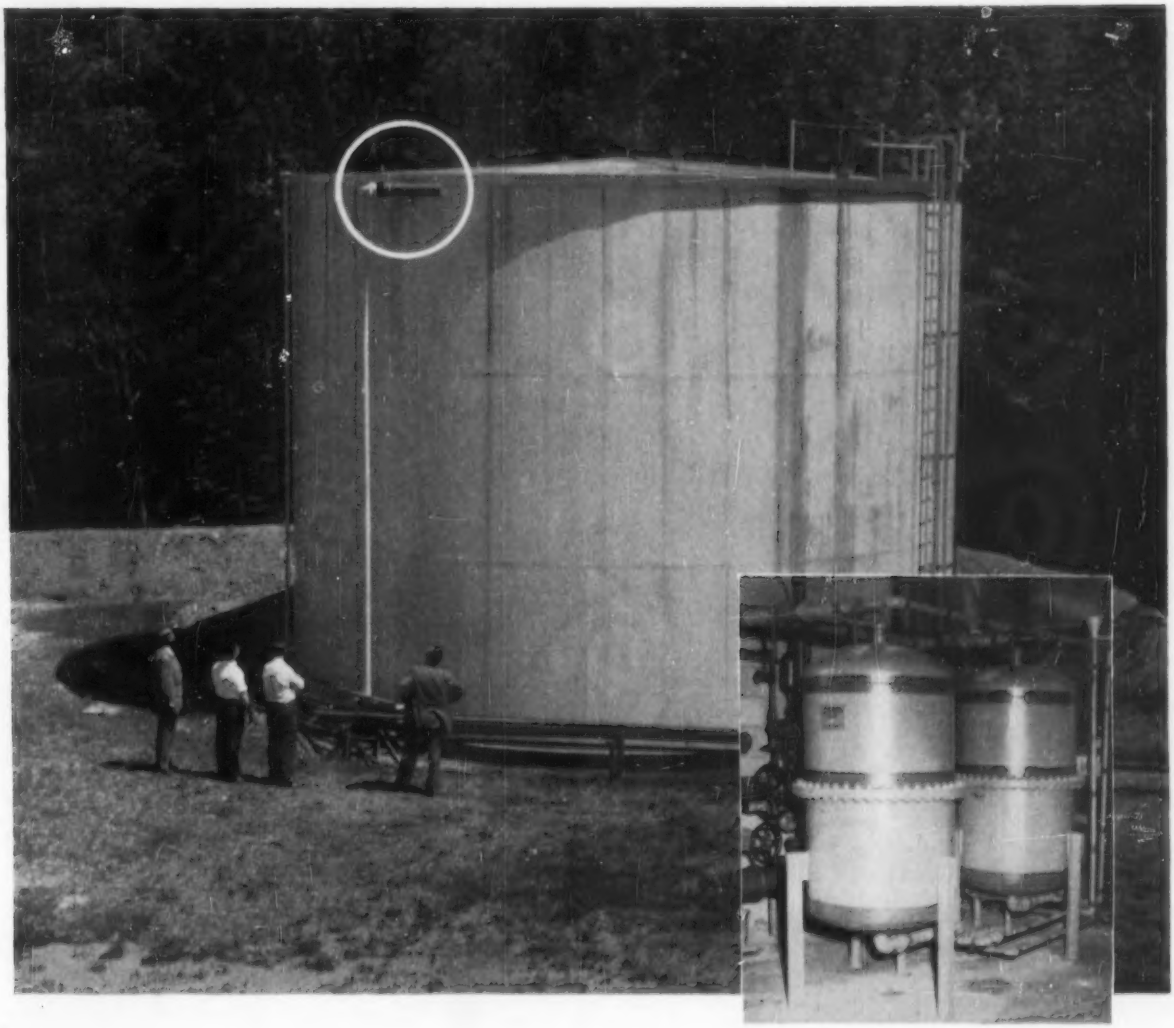
**Acoustica Associates, Inc.,** Glenwood Landing, L. I., New York, has elected **Paul M. Platzman** as vice president of sales and manufacturing. Other appointees were **Harold P. Baker** as vice president and treasurer, and **Ralph Reynolds** as technical sales manager.

**United States Steel Corporation** has appointed **E. E. McKean** of Piedmont, Calif., to a newly created position of general erecting manager for United States Steel's American Bridge division. Also announced was the appointment of **George W. Faulkner,** of Whittier, Calif., to succeed McKeen as erecting manager for the 11 Western states. He will be headquartered at San Francisco.

**The Baldwin-Hill Company,** Trenton, N. J., has acquired the Wabash, Ind., plant of the Eagle-Picher Company in negotiations recently completed in Cincinnati.

Under the terms of the purchase agreement Baldwin-Hill will take over all the assets of the plant in a straight cash settlement. It is the intention of the new owner to continue operations in Wabash along present lines, with no change in local personnel.

**Monsanto Chemical Company,** Research and Engineering division, will establish a special laboratory to do re-



# A blanket for this big baby?

## *Sure . . . it's in the two little tanks . . . a blanket of Foam*

The big tank is full of Styrene, great stuff for the plastics business.

A Styrene fire out of control, like any fire, can be dangerous. The best way to fight it? Throw a blanket of Rockwood FOAM over it.

On top of this big baby full of Styrene is the business end of a Rockwood Fixed FOAM System (in the circle). It'll throw a FOAM blanket over the tank in seconds — if a fire ever starts.

The FOAM liquid is kept, ready to go any time, in the Rockwood diaphragm-type storage tanks on the right.

Do you have a baby like this — full of some flammable liquid? Is a Rockwood Fixed FOAM System ready with a blanket — just in case? Use the coupon to send for the informative booklet.

**ROCKWOOD SPRINKLER COMPANY**

*Engineers Water . . . to Cut Fire Losses*

***Distributors in all principal cities***

**ROCKWOOD SPRINKLER COMPANY**
**Portable Fire Protection Division**
**1606 Harlow Street**
**Worcester 5, Mass.**

Please send me your illustrated booklet on Rockwood fire fighting products.

Name .....

Title .....

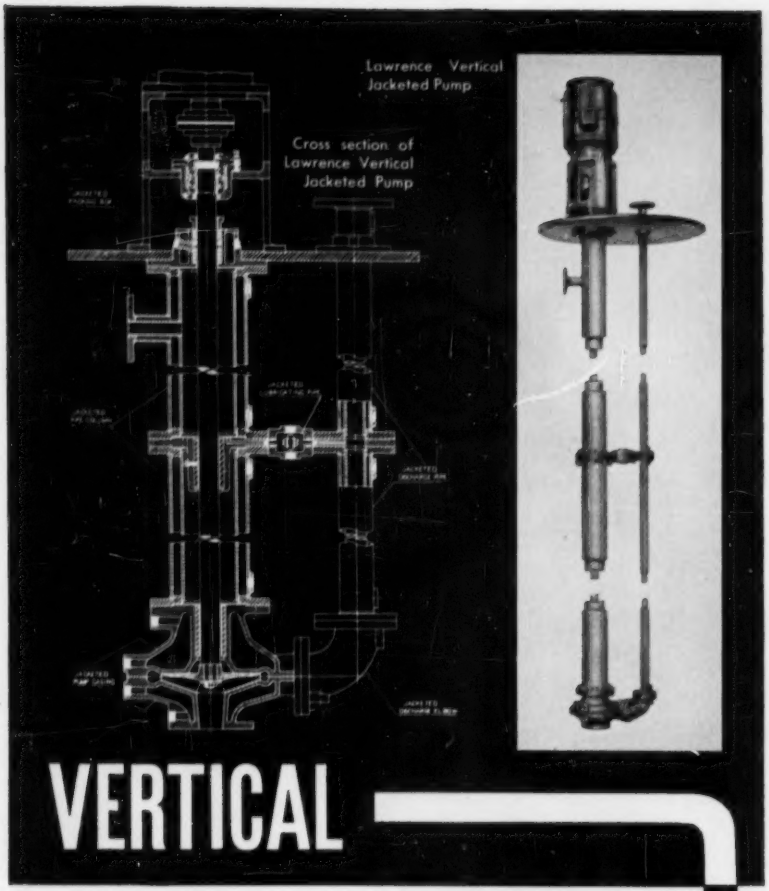
Company .....

Street .....

City ..... Zone .. State .....



For more data on advertised products, use Readers' Service Cards, last page.




VERTICAL

jacketed PUMPS

Lawrence vertical jacketed pumps are designed to pump liquids such as sulphur, phthalic anhydride, resins, waxes, etc., which tend to solidify or become viscous at low temperatures. The heating medium can be steam, dowtherm, etc.

The pump is jacketed throughout, i.e. — the pump casing, pipe column, discharge pipe and packing box. All heating spaces are vented and self-draining.

For submerged operation, these pumps are frequently made with only the pipe column, discharge pipe and packing box jacketed; the pump itself, not being jacketed.

If you have to pump liquids which must be maintained above a certain temperature to prevent solidification, write us the pertinent details. No obligation.

**Write for Bulletin 203-7.**

**LAWRENCE PUMPS INC.**
371 Market Street, Lawrence, Mass.


## Suppliers . . .

search and development work on problems relating to national defense and welfare which complement Monsanto's own long range projects.

**Herbert E. Morris** of Texas City, Tex., associate director of research for Monsanto's plastics division, has been named director of the new department and will assume his duties January 1.

**Koehring Company** president, Julien **R. Steelman**, and **Buffalo-Springfield** president, **Carl F. Greiner**, announcing the completion of plans to merge the two firms. The agreement was signed by all stockholders of Buffalo-Springfield and a representative of the Koehring Company Board of Directors. The merger became effective December 1.

**The Wright Chemical Corporation,** Chicago, has appointed **Lew M. Jacobsen** as national sales manager of the Fuel Oil Conditioning division. Jacobsen was formerly district manager for Pro-Kem Products, Inc.

**Minneapolis-Honeywell Regulator Company** has purchased Davies Laboratories, Inc., of Beltsville, Md., manufacturer of specialized high-speed data recording systems. The Davies electronic systems use magnetic tape and are designed for high-speed acquisition, reproduction and analysis of engineering and scientific data.

Wishart said activities of the Davies Laboratories would be integrated with those of Honeywell's Industrial Division at Philadelphia, producers of instrumentation for industrial use.

**Davison Chemical Company,** division of W. R. Grace & Company has appointed **E. Kyle Ruble** midwestern district sales manager of the Industrial Chemicals Division, with supervision of sales of silica gels, silicofluorides and other Davison products in twelve states extending from Nebraska to Ohio. He has been with Davison since 1938.

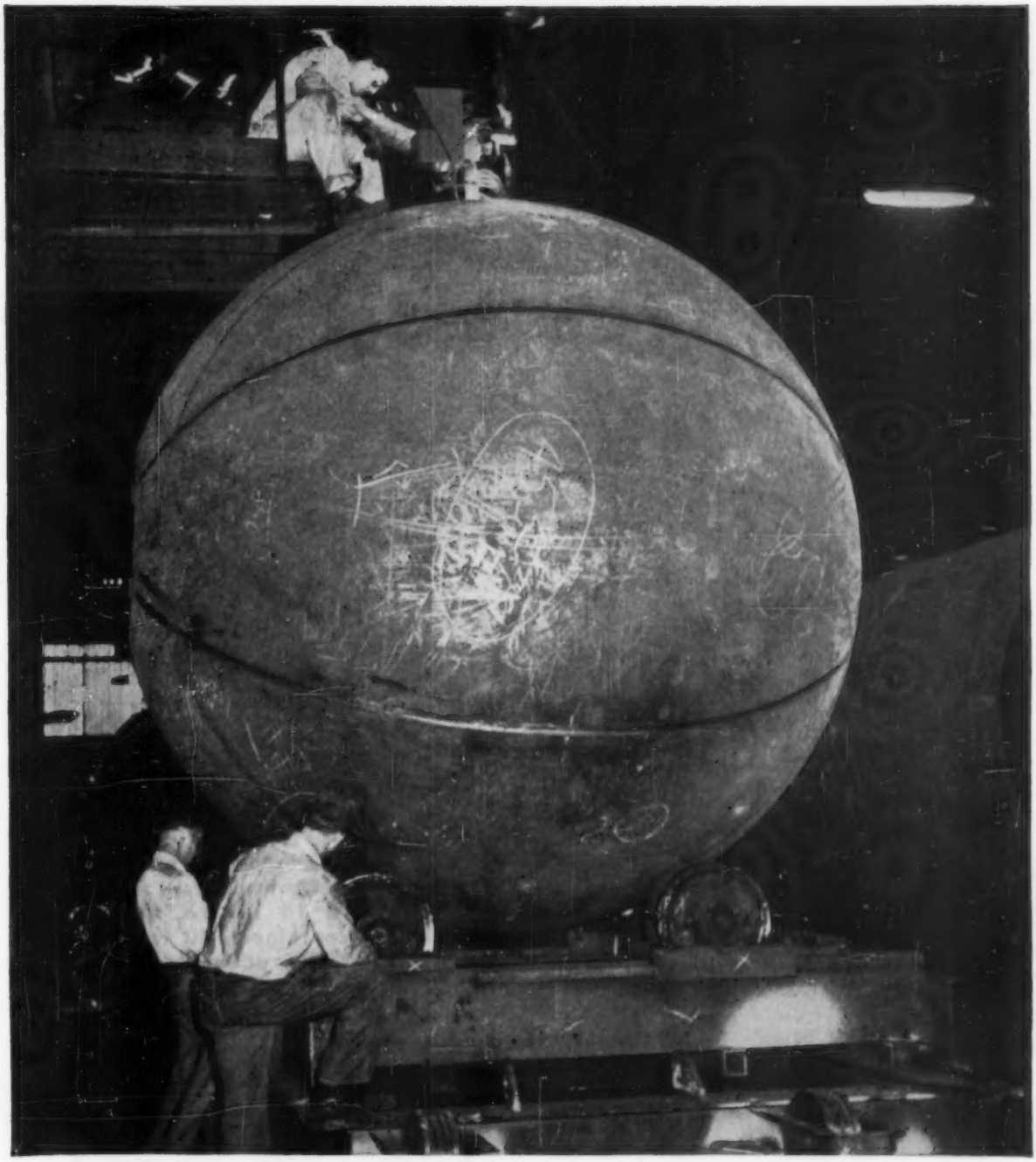
**Panellit, Inc.,** Skokie, Ill., has elected **Millard D. Shriver** vice president in charge of sales. In 1951 Shriver joined Panellit as product manager and was appointed general sales manager in 1954. He is a founder and member of the Instrument Society of America, serving as chairman of the national meeting in Buffalo in 1950 and as vice chairman of the 1953 meeting in Chicago.

**Kaiser Steel Corp.** has named **James A. Wiggs** sales representative at Phoenix, Ariz. In his new position, Wiggs will head the Phoenix office serving customers throughout Arizona.

Wiggs has been associated with the steel industry in the West for the past fifteen years. Before joining Kaiser Steel in 1950, he was with Bawlins Brothers and Keystone Tool & Supply in Los Angeles. For the past six years he has been a salesman with Kaiser Steel's southern district sales office in Los Angeles.

**Stauffer Chemical Co.** has appointed **Richard N. Stillman** assistant controller. In this new position, Stillman's duties will include special responsibilities for Stauf-


For more data on advertising products, use Readers' Service Cards, last page.



# NEED A KING-SIZE BASKETBALL?

This one is a spherical reactor operating at 650 psi and 850°. Graver ingenuity and skill fabricated the carbon steel outer shell, lined it first with 6″ of gunite, then with Type 321 stainless steel interior and fittings. For precision-built pressure vessels in alloys or carbon steel, call on Graver.

GRAVER®

**GRAVER TANK & MFG. CO., INC.**

EAST CHICAGO, INDIANA • NEW YORK • PHILADELPHIA • EDGE MOOR, DELAWARE
PITTSBURGH • DETROIT • CHICAGO • TULSA • SANDS SPRINGS, OKLAHOMA
HOUSTON • LOS ANGELES • FONTANA, CALIFORNIA • SAN FRANCISCO



For more data on advertised products, use Readers' Service Cards, last page.

**Shown here is the Model 38M Dempster - Dumpster handling two types of containers. Above a standard 15 cu. yd. bottom dumping container. At left and below a 10 cu. yd. Tilt dumping container in pick-up, haul and dumping positions.**

# Payloads Lifted, Hauled and Dumped by One Man and the DEMPSTER-DUMPSTER

TO ELIMINATE WASTE in time, labor and the expense of double-handling heavy salvable materials, this Dempster-Dumpster, installed in one of the nation's leading industrial plants, lifts, hauls and discharges 18-ton payloads with only one man, the driver.

Such heavy load requirements, of course, are the exception. But the important factor in the tremendous savings of the Dempster-Dumpster System is not capacity. It is the ability of only one truck-mounted Dempster-Dumpster, constantly on the move, serving many containers of various types and sizes, standard or special, built to meet the requirements of any plant.

Our records of hundreds of installations in plants of almost every known classification, show savings of from 60 to 90 per cent over previous methods. Moving materials from one point to another swiftly, economically, is a problem in every industrial plant in the nation. Most of these plants need the Dempster-Dumpster System.

Whether it's liquids, acids, rubbish, salvable, raw, finished, light, heavy or high temperature materials, there's a Dempster-Dumpster and containers, of 2 to 21 cu. yds. capacity, built to handle it. And all with only one man, the driver.

Can the Dempster-Dumpster System be used profitably in your plant? Let one of our engineers discuss it with you. *Dempster Brothers, Inc. . . . serving all industry throughout the nation.*

One Truck-Mounted
Dempster-Dumpster Handles Scores
of Containers . . . All Designs . . . All Sizes

6168

**DEMPSTER BROTHERS, 5126 Dempster Building, Knoxville 17, Tennessee**



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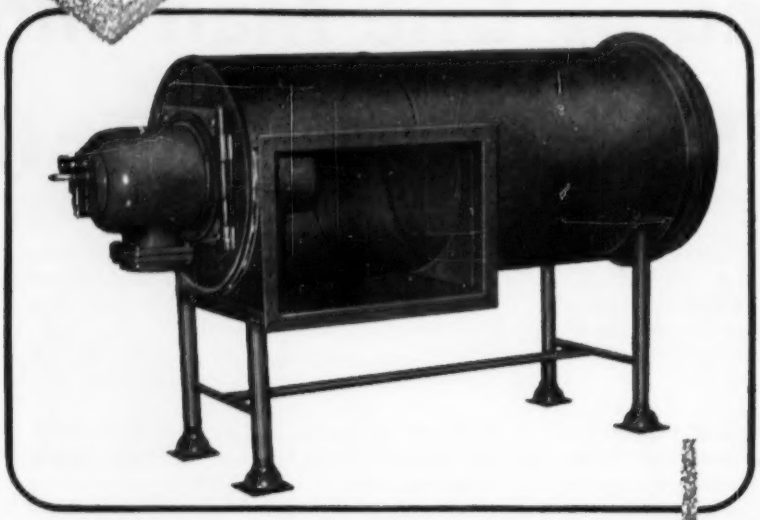
# THERMAL TYPE CA DIRECT FIRED AIR HEATERS



## COMPACT . . . EASILY INSTALLED

Readily fitted to ovens, kilns, spray dryers, etc., the THERMAL Type CA Air Heater is an ideal source of heat where products of combustion may be mixed with the air. Oil, gas or combination firing is available without change in heater construction.

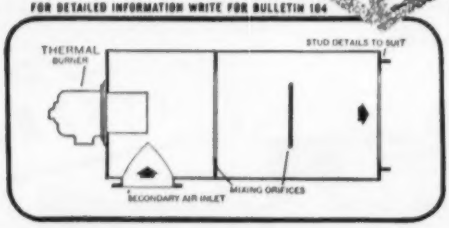
## NO REFRACTORY REQUIRED . . .

The THERMAL High Velocity Burner built into the heater permits combustion to be substantially completed within the burner itself. Thus the heater is basically a mixing chamber wherein the products of combustion are mixed with the air being heated. Refractory is not normally used. Successful applications have been made ranging from under 200,000 BTU/hr. to over 20,000,000 BTU/hr. and at all pressure levels.

FOR DETAILED INFORMATION WRITE FOR BULLETIN 104

## UNITIZED CONSTRUCTION

Initial cost and upkeep is kept at a minimum through the use of all welded, all metal construction. The CA Air Heaters are normally supplied as complete "package" installations.




OTHER THERMAL PRODUCTS & SERVICES → Gas, Oil & Combination Gas-Oil Burners • Heat Exchangers • Submerged Combustion • Combustion & Heat Transfer Engineering

# THERMAL

**Thermal Research & Engineering Corp.**

CONSHOHOCKEN • PENNSYLVANIA

REPRESENTATIVES IN PRINCIPAL CITIES


## Suppliers . . .

fer's banking relations. Prior to this appointment he had been chief of the company's accounting staff. Stillman graduated from Roanoke College and New York University, and joined Stauffer in 1952.

**Tracerlab, Inc.,** has appointed **Paul Byrne** as its new instrument division representative in northern California, Oregon, Washington, Nebraska, Wyoming, Montana, Utah and Idaho. Byrne is a graduate of the U. S. Naval Academy at Annapolis.

**Oronite Chemical Co.** has divided its eastern sales region into two sales districts. **E. J. Van Buskirk** has been appointed manager of the northeastern district; **B. W. Colaianni** has been named manager of the southeastern district; **J. H. Selby** has been appointed manager, special accounts, eastern sales region; and **J. R. Stitt** will continue to supervise Oronite's eastern regional sales and coordinate the activities of the new sales offices.

**General American Transportation Corp.** has elected **Sam Laud** chairman and **Lester N. Selig** chairman of the executive committee.

**Allis-Chalmers Manufacturing Co.** has opened a branch office in Allentown, Pa., under the management of **Ralph L. Haney.**

Haney has been associated with Allis-Chalmers since his graduation in 1942 as an electrical engineer from Lehigh University. He has been a sales representative in the firm's Boston district since November, 1946.

**Dorr-Oliver, Inc.,** has formed Dorr-Oliver Pty. Ltd., a wholly owned subsidiary in Australia. Beginning on January 1, 1957, the new company will design, market and service the complete line of D-O equipment in the Australia-New Zealand area.

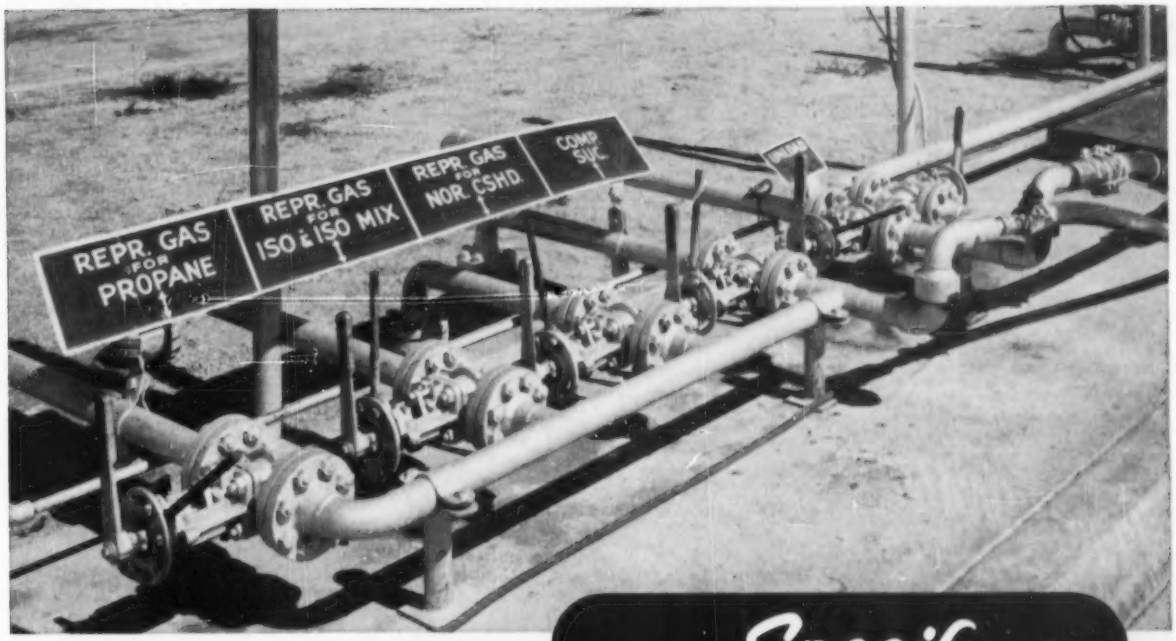
**D. U. Macintosh,** associated with D-O activities in Australia since 1933, will be managing director of the company. Hobart Duff Pty. Ltd., who has represented D-O interests for the past 27 years, will continue for the balance of 1956. **W. V. Hobart Duff,** managing director of Hobart Duff Pty. Ltd., will serve on the board of Door-Oliver Pty. Ltd. and act as adviser-consultant to the new company.

**American Potash & Chemical Corp.** has announced two promotions in the research department of the company's main plant at Trona, Calif.

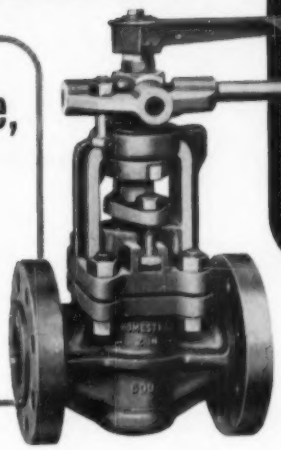
**Dr. Donald Garrett** has been named as assistant manager while **Stanley Cohen** has been appointed head of the new products section. Garrett succeeds **Harold Mazza** who recently was appointed manager of research at AP&CC's Los Angeles Plant.

**National Research Corp.** has named **S. Sydney Minault** to the position of vice president. Minault joined National Research in 1953 and has served as general manager of the company's equipment division for the past two years.

Born in England, Minault spent his youth in France, where he received his




for dependable, trouble-free control of "hard-to-hold" fluids . . .



# Specify HOMESTEAD Lever-Seald VALVES

**they provide sure shut-off...**

**ARE STICK PROOF...OPERATE INSTANTLY**

A positive, drop-tight seal and instant, stick-proof operation under all fluid, temperature or pressure conditions, is assured by the exclusive, built-in, Homestead Lever-Seald mechanism. This powerful lever-and-screw device not only presses the valve's tapered plug firmly into its seat to form a drop-tight seal, but also provides a positive means of relieving seating pressure just enough to overcome friction and permit easy operation. And because all operating parts and valve seating surfaces are fully protected in both the open and closed positions from the corrosive or erosive effects of line fluids, long, dependable, trouble-free service is doubly assured.

If "hard-to-handle" fluids are your problem, specify Homestead Lever-Seald Valves for your next installation or as replacements. You'll be glad you did.

We make them in metals and alloys to specification in sizes 1½" to 12", for pressures from vacuum to 1500 lbs., and for temperatures from 40° below zero to 1100°F. Dry seat, or pressure gun lubricated optional.

**For complete details and copy of VALVE REFERENCE BOOK No. 39-3, MAIL THE COUPON TODAY.**

**HOMESTEAD**
**VALVE MANUFACTURING COMPANY**
*"Serving Since 1892"*
P. O. BOX 45 CORAOPOLIS, PA.

Without obligation, send me Catalog 39-3 covering Homestead Lever-Seald Valves.

NAME _____ TITLE _____
COMPANY _____
ADDRESS _____
CITY _____ STATE _____


For more data on advertised products, use Readers' Service Cards, last page.

## Suppliers . . .

B.S. degree at the University of Paris. He also holds B.A. and M.A. degrees in mechanical engineering from Ohio State University.

**Diamond Alkali Co.** has appointed **Dr. Nelson V. Seeger**, Cuyahoga Falls, Ohio, to the newly-created post of associate director of exploratory research. Dr. Seeger, in his new position, will hold primary responsibility for the company's development and research activities in monomer, polymer and radiation chemistry. He will be located at the Diamond Research Center in Painesville.

**B-I-F Industries, Inc.,** has appointed **Frank D. Brindel** manager of the Berkeley office of B-I-F Pacific. Brindel is a graduate petroleum engineer from the University of Tulsa. His professional affiliations include the Instrument Society of America and the American Petroleum Institute.

**Paul V. Hennessy** has been named manager of the Los Angeles office of B-I-F Pacific. He received his B.S. degree in chemical engineering from the University of California. He is a registered professional engineer, state of California.

**The Conrad Creim Co.,** materials handling and construction equipment distributors, have been appointed franchise representatives for sales and service of Yale industrial lift trucks, according to an announcement by **Clyde R. Dean Jr.**, General Sales Manager, Yale materials handling division, **The Yale & Towne Manufacturing Co.**

Headed by **Conrad Creim**, the company headquarters are located in the new industrial park area of Seattle, Wash.

**OK Electronics Co.,** Syracuse, New York, has been appointed sales representative for Du Mont mobile radio communications system in north central New York state. The announcement is made by **C. J. Harrison**, sales manager of the mobile communications department, Allen B. Du Mont Laboratories, Inc.

**Ampco Metal, Inc.,** Milwaukee, Wisconsin, has announced the following companies as stocking distributors of Ampco Bronze Weldrod products: Gaspro, Limited, Honolulu, Hawaii; Georgia Supply Company, Jacksonville, Florida.

**Industrial Gasket & Packing Co., Inc.,** Oklahoma City, has been appointed distributor of Parker o-rings and other molded rubber products, it was announced by **D. A. Cameron**, general sales manager of Parker Appliance Company. President of the distributing firm is **Charles J. Donavan.**

**The Hays Corporation,** Michigan City, Ind., has appointed Imco Equipment Co., Oakland, as their exclusive representative in northern California. Founder of Imco Equipment Co. is **John T. Kirkland.**

**American Potash & Chemical Corp.,** has promoted **Joseph Adinoff** to senior development engineer, according to an announcement by **H. B. H. Cooper**, director of development engineering for the company.

Adinoff previously was chief engineer at AP&CC's Los Angeles Plant. Under the new assignment he will headquarter at the company's main office, also at Los Angeles.

**American Air Filter Co., Inc.,** has announced three organizational changes. **C. A. Pickett**, vice president and general manager of Illinois Engineering Company, an AAF subsidiary, has been named manager of AAF's sales department within the product and marketing division. **John J. Willis**, assistant manager of the heating and ventilating products department of AAF, will transfer to Illinois Engineering Company, Chicago, to become its sales manager and assistant to the general manager. **John W. Frazier**, assistant to the director of sales, has been appointed sales promotion manager.

**Infilco Inc.,** board of directors, has announced the election of **E. G. Kominek** and **A. A. Kalinske** to the offices of vice presidents of the company.

A graduate in chemistry from the University of Chicago, Kominek is a registered professional engineer. During his nineteen years with Infilco, Kominek has been research chemist, head of the Industrial Waste division, assistant sales manager and general sales manager, a position which he now holds.

A. A. Kalinske has been director of research and development for Infilco for the past ten years. A graduate in civil Engineering of the University of Wisconsin where he later taught hydraulics and

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## Suppliers . . .

sanitary engineering, Kalinske is an expert in the field of fluid mechanics.

**Ledeen Manufacturing Co., Inc.,** has moved to its new home at Gilman Road and Garvey Boulevard, El Monte, California. The new plant also serves as headquarters for Engineering Products Co., a subsidiary of Ledeen, Inc., and distributors of mechanical power transmission and materials handling equipment.

**Stanolind Foundation, Inc.,** has awarded 16 fellowships at 15 colleges and universities. The fellowship grants provide for graduate work in basic fields of study. Each fellowship pays all tuition and fees for the recipient, and provides him with $1500 for the academic year. Some of the 16 fellowships, and their recipients are:

**Petroleum Engineering:** Bobby W. Cannon, University of Oklahoma, Norman; Robert L. Paulsell, Pennsylvania State University, University Park; William R. Landcaster, Texas A. & M. College, College Station; Richard B. Banks, University of Texas, Austin; Kenneth E. Gray, University of Tulsa, Tulsa.

**Chemical Engineering:** L. Stanley Eubanks, The Rice Institute, Houston.

**Mechanical Engineering:** Robert L. Lowery, Oklahoma A. & M. College, Stillwater, Oklahoma.

**Chemistry:** Thomas J. Clark, Kansas State College, Manhattan, Kansas.

**Geo-Chemistry:** Bruce R. Doe, California Institute of Technology, Pasadena.

Stanolind Foundation, Inc., was created and is supported by Stanolind Oil and Gas Company, Tulsa. This is the 20th year of the Stanolind fellowship program, which was inaugurated in 1937 with one fellowship in reservoir engineering at the University of Texas.

**Paul Hardeman, Inc.,** constructors-engineers, has announced the merger of the various subsidiary companies formerly in the Hardeman group with Paul Hardeman, Inc. All activities will be carried on under the name of Paul Hardeman, Inc.

All the activities of **J. B. Gill Co., Wall Cryogenics, Inc., Climate Conditioning Corp., Systems Engineering Co.,** and **Electronetics Corp.** have been consolidated and became a part of Paul Hardeman, Inc.

**Midwest Instruments Inc.,** and **Magnecord, Inc.,** have agreed on terms for a merger. This was announced jointly by **M. E. Morrow,** chairman of the board of Midwestern Instruments and **Barrett Wendell,** chairman of Magnecord. The merger plans, which have been approved by both boards of directors, will be submitted to stockholders of both companies for immediate action.

Terms of the agreement call for an exchange of securities, with issuance of Midwestern Instruments common in exchange for all Magnecord common stock. American Research and Development Corporation, Boston, is a major investor in Magnecord.

**Bailey Meter Co.,** has acquired the trade name, know-how, and other assets of Metrotype Corp., Michigan City, Ind. Key personnel will continue in the engineering and manufacture of "Metrotype Systems" under the new management.

For the present, engineering and manufacturing operations will continue in Michigan City as the Metrotype division of Bailey Meter Co. Eventual complete integration with the Bailey organization in Cleveland, Ohio, is planned.

**H. K. Porter Co., Inc.,** Lacledе-Christy Co. division, has appointed **Thomas J. Carbine,** Philadelphia district sales manager. Carbine's sales district includes eastern Pennsylvania, parts of New Jersey and West Virginia, Maryland, Delaware, Virginia, and the District of Columbia. Sales representatives in this newly established sales district are **Norman W. Harris** and **Kenneth R. Bartholomew.**

Carbine graduated from Villanova University, and later completed a course in Ceramics at Penn State University.

**Emery Industries, Inc.,** has appointed **John V. Killheffer, Jr.,** to its research staff. He will be associated with the plasticizer group of the process research section under the supervision of **Dr. C. A. Sprang,** where he will work on both new and current plasticizers.

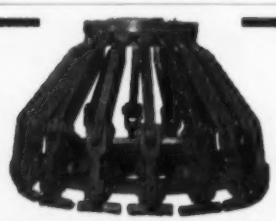
Prior to joining Emery, Killheffer was a chemist with the organic chemicals department of E. I. du Pont de Nemours & Co. He holds a B.S. degree from the Massachusetts Institute of Technology and M.S. degree from the University of North Carolina.

**Walsh Refractories Corporation** held a three-day sales conference October 24-26. Highlights of the conference included a plant tour of the company's Vandalia, Missouri, factory and clay pits.

Thirty-five sales representatives attended the meeting which was under the supervision of **A. J. Tomasek,** president, and **W. K. Schweickhardt,** vice-president and sales manager.

**Motorola, Inc.,** has named **Joseph P. Jatis** manager of two-way radio service training according to an announcement by **John Tansey,** national service manager of Motorola's communications and electronics division.

In his new position he will be responsible for all of the service clinics held



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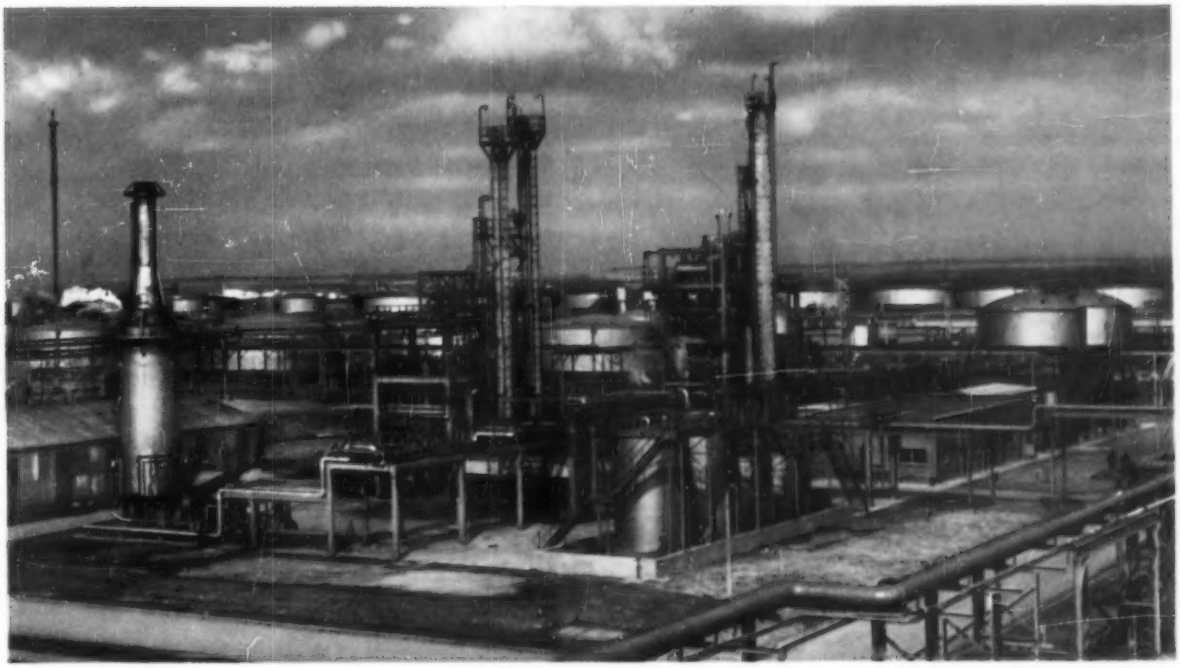

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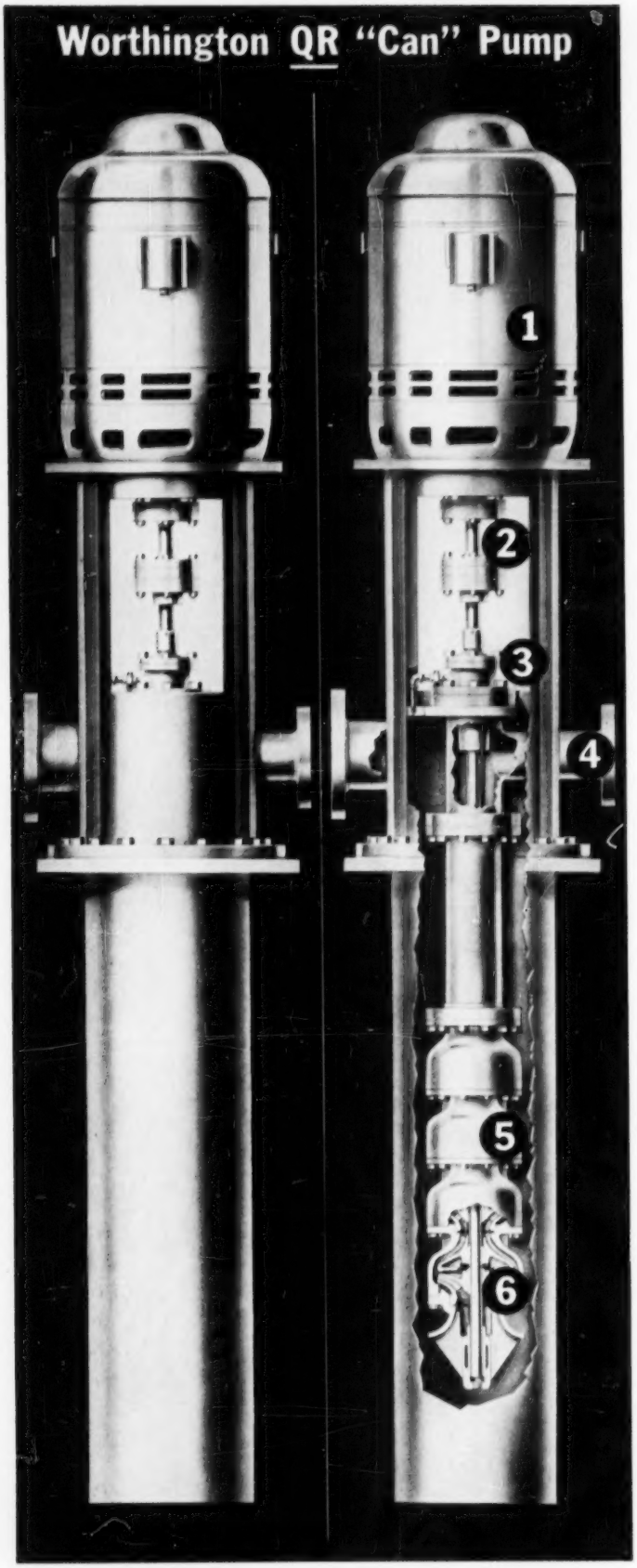


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In every point of operating efficiency, the Worthington QR Vertical Process Pump has proven superior. Talk to your Worthington engineer about your pump requirements. Worthington Corporation, A & SP-Pump Dept., Section C.6.2, Harrison, N. J.

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## Suppliers . . .

throughout the U. S. each year as well as the service classes held at Motorola's factory in Chicago.

Jatis has had experience in both the manufacturing and servicing ends of electronics. Prior to his promotion he was assistant to the national service manager; he has been with Motorola since 1935.

**Olin Mathieson Chemical Corp.** has named **Harry E. Gude** general manager of the Omal Rolling Mill of the Aluminum division. The plant, now under construction at Omal, Ohio, near Clarington, will have the capacity to handle 60,000 tons of aluminum a year.

Prior to joining Olin, Mr. Gude was division superintendent of stainless steel at the Gary Sheet and Tin Mill of United States Steel corporation, Gary, Indiana.

**Yale & Towne Manufacturing Co.,** Yale materials handling division has appointed **Francis J. Dunleavy**, director of pricing and budget control, to the position of assistant general manager. Dunleavy, a Yale executive since 1951, succeeds **John T. McCarley** who has been named general manager of the company's new west coast plant presently under construction at San Leandro, Calif.

The new assistant general manager's business career started in 1941 when he was appointed chief cost accountant of Bendix Aviation. Between 1945 and the time he joined the Yale organization, he was associated with the American Pulley Company as chief works accountant and later assistant controller. Dunleavy, a native of Philadelphia, is a graduate of Niagara University.

**B-I-F Industries, Inc.,** has transferred **Theodore R. Zatkovich** from Pittsburgh to Chicago to take over the duties of district sales manager. Zatkovich will be in charge of both industrial and municipal sales. He is a graduate mechanical engineer from the University of Pittsburgh.

At the same time **Gerald E. Biepe** was promoted to district engineer for water and sewage works sales and **M. H. Strickland** to district engineer for petroleum and industrial sales in the mid-western area.

**Beckman Instruments, Inc.,** has sent **Edward H. Cherniss,** International Division Manager on an eight weeks' tour of Western Europe, during which time he will check construction progress on Beckman's new manufacturing plant in Munich, Germany.

Beckman Instruments, G.m.b.H., a wholly-owned subsidiary of Beckman Instruments, Inc., is the first manufacturing facility in Munich to be established by an American firm.

**The Girdler Company,** Votator Division, has announced the appointment of **Bartley A. Greenwell** as midwest district manager with headquarters in Chicago. The Girdler Company, Louisville, is a division of the National Cylinder Gas Company, Chicago.

Greenwell received his B.S. degree in mechanical engineering at the University of Kentucky. During World War II he served as a pilot in the United States Air Force. Before becoming associated with the Votator Division as a sales engineer in April, 1954, he was the president and

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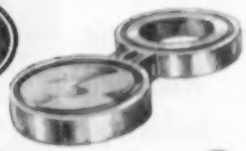

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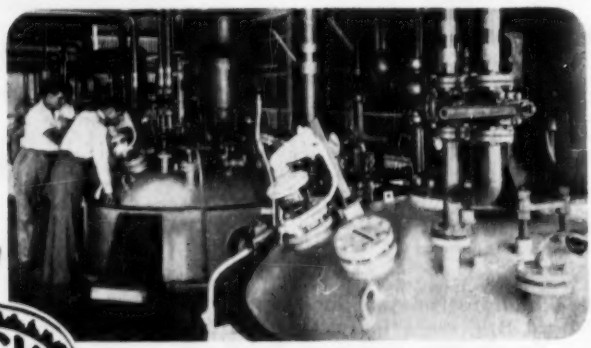

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Also Builders of Power Farming and Sawmill Machinery

## Suppliers . . .

general manager of his own company, Oxygen Service Company, Inc., of Kingsport, Tenn.

**Kaiser Steel Corporation** has appointed **Mark T. Anthony,** assistant to the vice president and general manager. He succeeds **A. F. Scarr,** recently named assistant general manager of Kaiser Center, Inc., Oakland.

Anthony joined Kaiser Steel in 1946 as assistant to the market consultant and later served as assistant director of the company's general planning department. In 1955, he was named assistant manager of Kaiser Steel's central district sales office in Oakland.

**E. I. du Pont de Nemours and Company, Inc.,** has appointed two assistant general managers, **Dr. William C. Kay** for the organic chemicals department and **Ernest R. Bridgwater** for the newly created elastomer chemicals department. Both appointments are effective January 1.

Dr. Kay, director of manufacture of the organic chemicals department, succeeds **Dr. George E. Holbrook** who was named general manager of the new elastomer chemicals department. Bridgwater has headed up sales activities of the rubber chemicals division, later the elastomers division, since 1929.

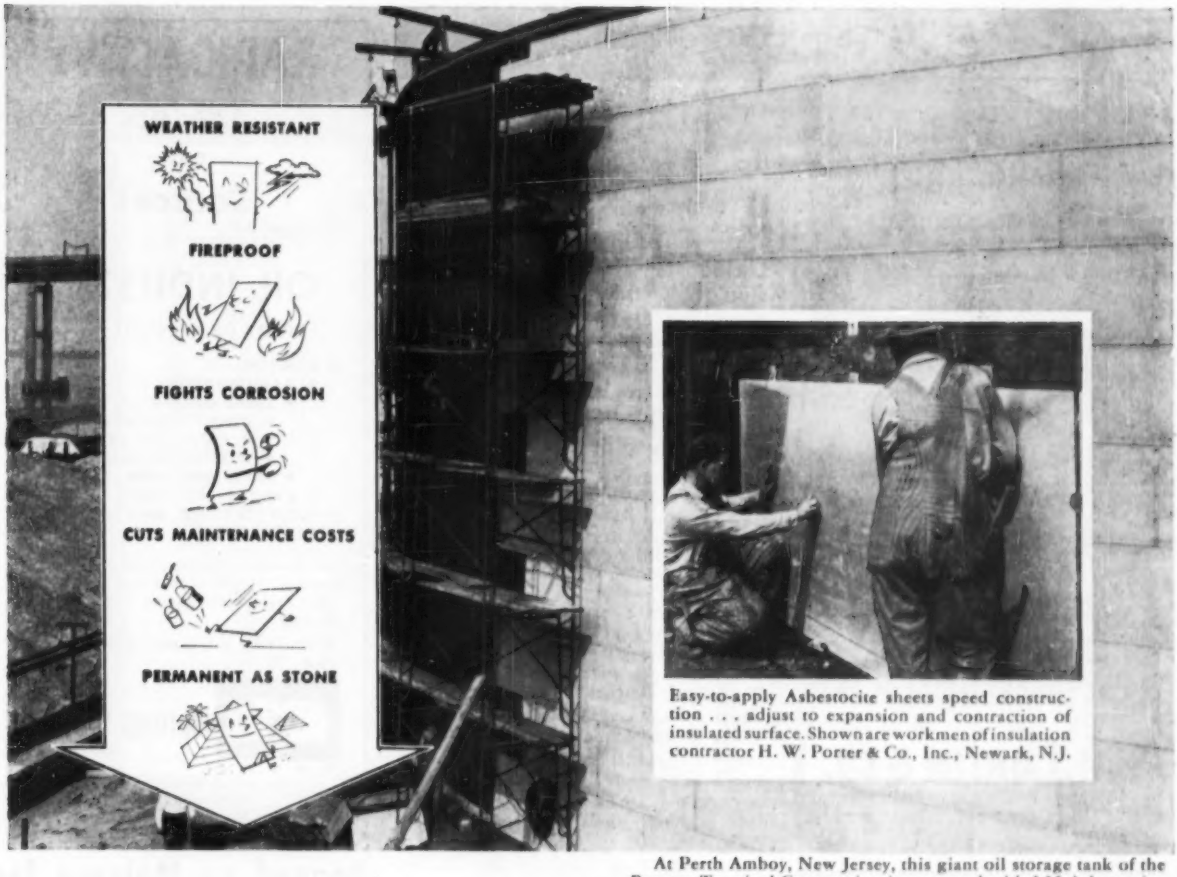
**United States Steel Corporation** has appointed **Erwin F. Burnett** manager, commercial research section of the Dallas headquarters office of U. S. Steel's oil well supply division.

Burnett succeeds **Neal K. Schnaitter,** who has been transferred to the products division of U. S. Steel as assistant to vice president-sales in the division's New York office.

**Olin Mathieson Chemical Corporation** has named **Edward Hartshorne** general manager of the Nuclear Fuel Division. Hartshorne was formerly executive vice president and a member of the board of directors of Bradley Container Corporation of Maynard, Mass., formerly a subsidiary of Olin Mathieson. Prior to that he was manager for the research and development department of the film division of the corporation. A graduate of the Massachusetts Institute of Technology, he has been affiliated with Olin since 1934.

**Roots-Connersville Blower Division** of Dresser Industries, Inc., has appointed **G. M. Wallace & Company** of Denver, Colo., as field application engineers for all Roots-Connersville products. G. M. Wallace & Company headquarters are in Denver with offices in Salt Lake City, Utah and Butte, Montana. Territory assigned to them includes Colorado, Wyoming, Montana, Utah, New Mexico, eastern Nevada, southern Idaho and western Texas. G. M. Wallace & Company is headed by **G. M. Wallace** who, prior to forming his present company, was Assistant Sales Manager for the Bailey Meter Company.

**General Electric Company** has opened its Construction Materials Division's Great Lakes district regional ware-

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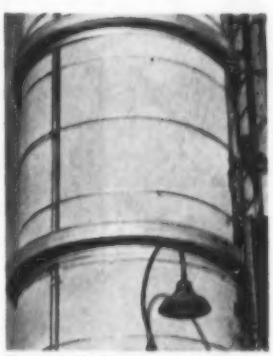
J-M Asbestocite is made of asbestos and cement combined under tremendous pressure into a uniform, monolithic sheet. Its stone-grey color provides a handsome appearance. Write for free brochures IN-121A and IN-173A. Address Johns-Manville, Box 14, New York 16, N. Y. In Canada, Port Credit, Ontario.



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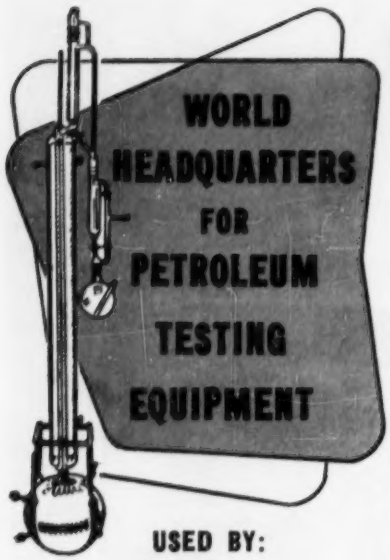


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## Suppliers . . .

house and sales offices. The new building has an area of approximately 18,000 sq. ft. The warehouse portion of the building is 15,000 square feet, the other 3,000 square feet is air-conditioned office space for the district's sales and commercial service personnel.

**Laclede-Christy Company Division,** H. K. Porter Company, Inc., has appointed **Glen H. Lufcy** superintendent at the Ottawa, Ill. works. Lufcy was in charge of quality control at Ottawa from 1954 until his recent promotion. He is a graduate ceramic engineer and a member of the American Ceramic Society.

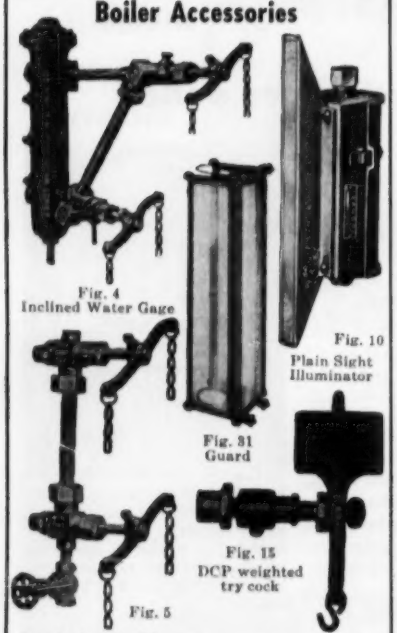
**American Potash & Chemical Corp.** has named **Dr. David Stern** assistant manager of the Whittier, Calif., research laboratory. Stern previously was head of the research lab's electrochemicals section since he joined the company in April of 1955.

Prior to joining AP&CC, Stern was with Western Electrochemical Co. which later became a part of American Potash & Chemical Corp.

**Diamond Antenna & Microwave Corp.,** Wakefield, Mass., has elected **Albert S. Hovannesian** Arlington, Mass., president and treasurer. Hovannesian served as vice-president and manager of the original Diamond Microwave Corp. Other changes are **Daniel K. Dorian,** Watertown, Mass., formerly director of engineering of the Tung-Sol Electric Co., and now vice-president of the new corporation, and **Leon R. Garabedian** of Belmont, Mass., business consultant.

**Uniform Tubes, Inc.,** Collegeville, Pa., has appointed **Fred G. Stroke** to represent the company in the New England states and in the province of Quebec. Stroke is a graduate of M.I.T. and has served as a metallurgist with the Atomic Energy Commission and as chief metallurgist with several industrial concerns.


**ERNST**
**Boiler Accessories**




Standard vertical bronze water gage, 350 pound

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**ERNST WATER COLUMN & GAGE CO.**
**Livingston, N. J.**



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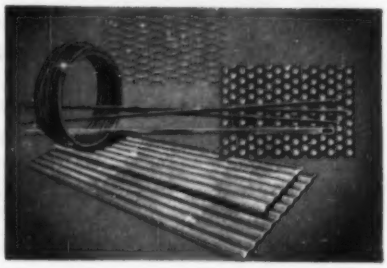

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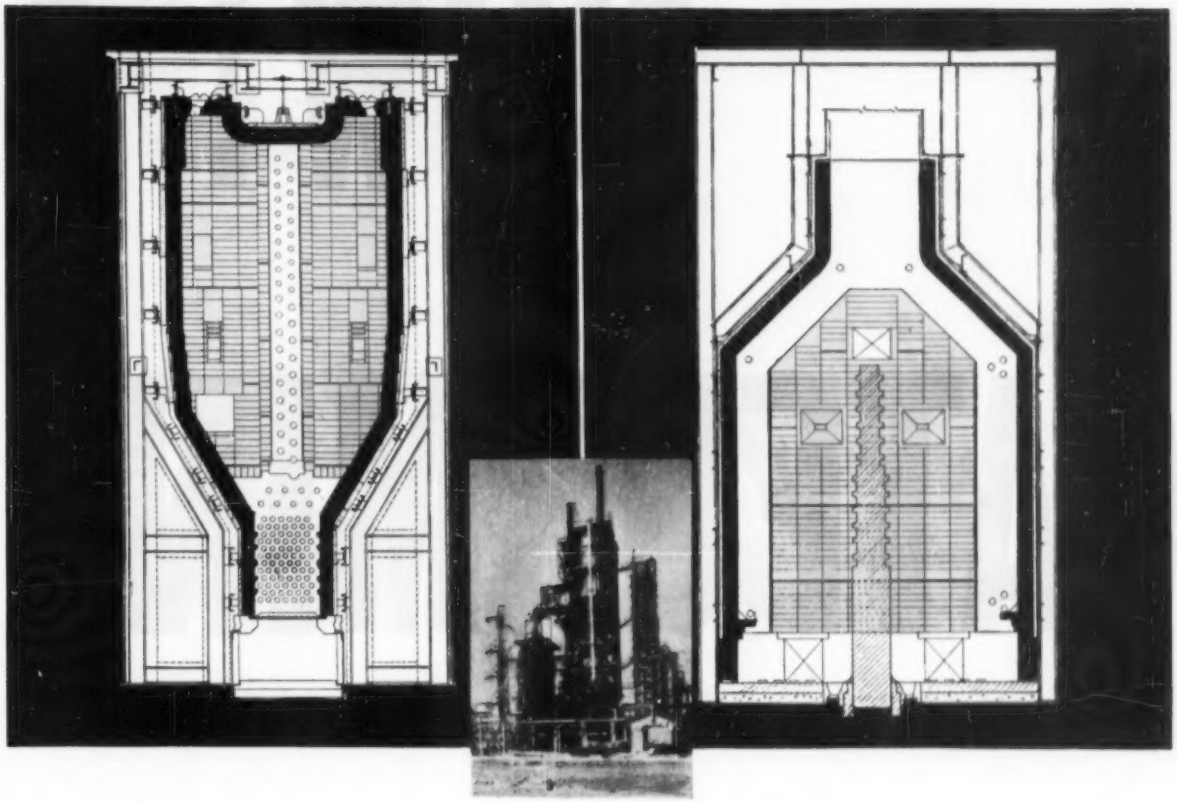
# *Profitable trends in the use of refractories*



## Laclede-Christy offers simplified way to get exact-purpose refinery refractories

It's highly profitable, of course, to use refractories exactly suited to each application. There's a simple way to do this. That is to rely upon one source which offers you each refractory type and grade that you may need—plus the quality and service you expect.

Laclede-Christy produces a variety of castable refractories for refinery use—to meet a wide temperature range. Two are particularly successful in refinery vessel applications—Porelite V.L. for its high insulating properties and lightness, and Firmcast for its extra strength and abrasion resistance.

Where you may need suspended arch and sectionally supported wall construction, Laclede-Christy again provides exact-purpose refractories. In fact, Laclede-Christy offers the most extensive experience obtainable in the engineering of suspended arch and wall construction.

If you need help to determine your exact-purpose refractory, Laclede offers that too. So, for a profitable trend in your use of refractories, get together with Laclede-Christy soon. A representative is nearby.

**LACLEDE-CHRISTY COMPANY**

**DIVISION OF H. K. PORTER COMPANY, INC.**

**2000 Hampton Avenue · St. Louis 10, Missouri**



For more data on advertising products, use Readers' Service Cards, last page.

# NOW! A CATFORMING

Here's important news for refiners who are finding it increasingly difficult to meet today's higher octane requirements with present processes and catalysts. Atlantic offers an advanced Catforming catalyst designed to do a better, more economical job. The new catalyst combines ability to make higher octane quality products and an improved stability. These catalyst qualities mean greater process flexibility, and they are applicable in your present equipment. For full information on Catforming, write, wire or call The Atlantic Refining Company, P.O. Box 8138, Philadelphia 1, Pa.




For more data on advertised products, use Readers' Service Cards, last page.

# NEW

# CATALYST

## HIGHER GASOLINE OCTANES THROUGH PENTAFINING

You can convert the low-quality n-paraffins ($C_5$, $C_6$, $C_7$) in your gasoline pool to high octanes! Pentafining, the process developed by The Atlantic Refining Company, makes it possible. For full particulars, write today to The Atlantic Refining Company, P. O. Box 8138, Philadelphia 1, Pa.

it's the **CATALYST** that counts

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PETROLEUM REFINER

# Classified Ads

**Petroleum Refiner New Classified Rates**

**RATES:** **Regular Classified** (undisplayed) set in this size type: **20 cents per word. Minimum charge, $4.** Blind box address in our care counts six words. Replies forwarded without charge. **Display Classified ads,** set in suitably larger type with ruled border, **$12.50 per column inch. Ten** percent discount for two or more insertions of same copy in consecutive **issues. All Classified ads payable in advance.** Copy deadline: 25th of month preceding date of issue. Send copy and checks to: Classified Advertising, Petroleum Refiner, P. O. Box 2608, Houston, Texas.

* * * * * * * * * * * * * * * * *

**HELP WANTED**

## Chemists
## Physicists
## Laboratory Technicians

**For employment in a new petrochemical plant near Houston. Modern well equipped laboratory. Principal products are butadiene and avgas. Experience in hydrocarbon analysis desirable. Send resume including details of education, experience, and salary requirements to C. E. Leach—**

**TEXAS BUTADIENE & CHEMICAL CORPORATION**

P. O. Box 777 Channelview, Texas

**HELP WANTED**

## CHEMICAL ENGINEERS

Major Oil Company has openings for Chemical Engineers in several phases of process engineering. Locations near New Orleans and south Arkansas, in booming industrial areas where climate and natural advantages make living more enjoyable for all the family. Attractive salary and benefits program. In reply give age, education, experience and salary expected. Pan-Am Southern Corporation, P. O. Box 2, New Orleans 6, Louisiana.

**SUPERINTENDENT of OPERATIONS**

Petroleum refinery, re-locate.
Our fee paid. Salary to $18,000.

**QUINBY EMPLOYMENT SERVICE**

406 Bankers Mtg. Bldg., Houston, Texas

● CHIEF CHEMIST with at least six years refinery experience. Must be aggressive and have some asphalt experience, for an 18,000 BPD independent Texas refinery. Also chemist with at least three years experience to handle gasoline research as well as other light oil products. Apply Box 253-R, Petroleum Refiner, Box 2608, Houston 1, Texas.

# ESSO RESEARCH

## Chemists and Chemical Engineers

MS or PhD Chemists or Chemical Engineers with up to seven years' experience sought in an expansion program for:

1. Development of new and improved petroleum products—fuels, lubricants, waxes, rust preventives, agricultural chemicals.
2. Utilization of by-product petroleum fractions in petrochemicals (plastics, resins, protective coatings, synthetic rubber, etc.) Also catalyst development and exploratory work on reactions leading to new manufacturing processes.

Give full details of education, experience, desired salary, availability date and references. All inquiries will be considered promptly and held confidential.

**ESSO RESEARCH AND ENGINEERING COMPANY**

(Chief Technical Subsidiary—Standard Oil Company [New Jersey])

Esso Research Center
Employee Relations-C
P. O. Box 51 Linden, N. J.

HELP WANTED

EHRHART & ASSOCIATES, INC.
*Engineers and Constructors*

## Engineers

**PROCESS • PROJECT MECHANICAL**
**for**
**SAN FRANCISCO**
**and**
**LOS ANGELES**

Men with 5 to 15 years experience in design and design supervision of process plants, refineries or chemical plants are required for small rapidly growing company with opportunities at senior levels. Company is engaged in engineering-construction projects for major West Coast Companies.

Company paid hospitalization, life insurance and vacations.

Personal interviews will be arranged.

**EARHART & ASSOCIATES, INC.**
*Engineers and Constructors*
**417 SOUTH HILL STREET**
**LOS ANGELES 13, CALIFORNIA**

## CHEMICAL ENGINEER

Expanding Houston refinery has opening for graduate Chemical Engineer with minimum of two years petroleum refinery experience. Excellent salary.

Send complete resume to

**P. O. Box 5008**
**Harrisburg Station**
**Houston 12, Texas**

HELP WANTED

## JOB OPPORTUNITY

Engineer with 5 or more years experience in Refinery Operation. Position in Development Department making economic studies of existing and proposed Refinery and Petro-Chemical Operations. Southern location—Salary Open. Write Box 252-R Petroleum Refiner Houston, Texas.

## PONTIAC REFINING CORP.

A well established growing independent refiner has three openings for experienced refinery personnel:

**PROCESS DESIGN ENGINEER**
With a minimum of five years design experience and ability to work with mechanical design engineers. Scope of position is open and depends on available person.

**OPERATIONS ANALYST**
A general technologist with understanding of processing and ability to evaluate charge stocks and processing operations. Also requires thorough familiarity with product blending and the economics involved.

**SAFETY AND FIRE SUPERVISOR**
This position requires a person familiar with refinery operations and the safety and fire hazards of refineries, as well as the ability to organize and carry on a complete safety and fire-fighting program in a small organization.

Write, giving resume, to
PONTIAC REFINING CORP.
P. O. Box 1581, Corpus Christi, Texas

HELP WANTED

## Pontiac Eastern Corp.

A new, complete refinery, currently under construction near Hattiesburg, Mississippi includes Thermafor Catalytic Cracking, Fluid Coking, Sulfuric Alkylation, Platforming, Unifining and Sulfur Recovery.

Applications are now being taken for the following positions:

### Plant Superintendent
A mature and responsible person with thorough training and broad experience in both operation and maintenance of petroleum refinery equipment to have charge of both of these functions in the refinery, the pipe line and the terminal.

### Chief Engineer
An engineer with general technological experience to have charge of both process design and mechanical design work. Scope of position is open and dependent on available person.

### Chief Chemist
Responsible person with experience in petroleum product blending and familiarity with latest refinery laboratory methods.

### Process Foreman
An operations supervisor of broad experience to work under the Plant Superintendent and to be in charge of all operating units.

### Maintenance Foreman
An experienced supervisor familiar with all types of refinery equipment to work under the Plant Superintendent and to be in charge of maintenance and small construction in the refinery, pipe line and terminal.

Write, giving resumé including experience with processes listed, to

**PONTIAC EASTERN CORP.**
P. O. Box 1581, Corpus Christi, Texas
Applications for other positions will be taken at a later date.

## Refinery Chemical Engineers

**(Ages 25 - 38)**

A major integrated U. S. oil company operating in South America has career employment opportunities in the rapidly expanding organization of a large modern refinery for qualified refinery chemical engineers. Vacancies exist in positions at levels requiring 4½ to 10 years oil refinery experience in work involving (1) process control, engineering, development and design of process equipment, (2) economic studies of the application of new processes and the modification of existing processes (3) special studies in evaluating major problems related to petroleum refining. Salary, including bonus, $14,500-$18,500 depending on qualifications and experience. Excellent employee benefits including home vacations with travel expenses. Send complete resume of personal data and work experience. Replies held in strict confidence and interviews arranged for qualified applicants.

**Box 480**
**Dept. L-14**
**NEW YORK 19, N. Y.**

## Chemical Project ENGINEERS

**2 to 7 years experience**

Newly organized section in our Engineering & Construction Division at Pittsburgh has openings for several project engineers. Need men with broad background in chemical and petrochemical plant work who have had process or project experience. Work includes the coordination of diverse process and project aspects involving other sections.

Must be familiar with the various equipment in Chemical Plants and must have an understanding of heat transfer, fluid flow, distillation, absorption and instrumentation. Assignments require the ability to maintain customer relations; to advise draftsmen on plant layouts, and to instrumentate process flow sheets.

Write giving details of experience and salary requirement to: Personnel Manager, Koppers Company, Inc., 108 Koppers Building, Pittsburgh 19, Pa.

**REFINER**
**Classified Ads Bring**
**RESULTS**

# CLASSIFIED ADS

HELP WANTED

## CHEMICAL ENGINEER

An expanding program in the new and extensive facilities at Parma, Ohio, requires a chemist or chemical engineer with training or experience in petroleum refining or coal hydrogenalysis procedures for research and engineering in the field of utilization heavy residues.

As the newest of several major research centers of Union Carbide and Carbon Corporation, the Laboratories at Parma also offer excellent opportunities for research in Solid State Physics, Electrochemistry, and High Temperature Chemistry, Carbon and Graphite.

Mail resume and college transcripts to:

**G. H. Murray, Jr.**
*Personnel Director*
National Carbon Research Laboratories
P. O. Box 6116
Cleveland 1, Ohio

HELP WANTED

## OPPORTUNITY

Supervisory research opening in Lion Oil, A Division of Monsanto Chemical Company for qualified person with at least 5 years experience in the formulation of petroleum products and non-automotive petroleum specialties. Refining experience desirable but not essential. Location El Dorado, Arkansas. Integrated refinery operations of moderate size. Real opportunity for advancement.

*Address replies to:*

E. R. Coley
Technical Recruitment Coordinator
Lion Oil Company, A Division of
Monsanto Chemical Company
El Dorado, Arkansas

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Steam Power Plants
Petroleum Refineries
Electrical Sub-Stations
Hydro Electric Projects

Send Resume to
Manager of Employment & Placement
Industrial Relations Division

BECHTEL
CORPORATION
220 Bush Street
San Francisco 4, Calif.

For an immediate personal interview you may phone:
Paul Keating, Plaza 7-4400, New York City
Joe Braddick, Fairfax 3-2401, Houston, Tex.
Bill Milligan, Tucker 1549, Los Angeles, Calif.
Don Palmer, Douglas 2-4032, San Francisco, Calif.

## PETROLEUM ENGINEERS

**SENIOR ENGINEERS**

Graduate Engineers with minimum seven years experience in all phases of Producing Operations including Reservoir Engineering, pressure maintenance, secondary recovery, and all types of primary depletion plus some knowledge of facility requirements. Initial assignment will be in New York Office in newly organized specialty study group concerned with long range planning of Arabian operations. Salary commensurate with background and experience.

**GRADUATE ENGINEERS**

Electrical, Mechanical, Chemical or Petroleum Engineers with minimum two years experience in Petroleum Production Reservoir field who are interested in Production Reservoir Engineering and Reservoir Exploitation. Initial assignment New York Office. Salary commensurate with background and experience.

**DRILLING**

Graduate Mechanical or Petroleum Engineers with minimum five years experience. For exploration and producing operations in Saudi Arabia. Salary open, plus liberal living allowance.

Write giving full particulars regarding personal history and work experience.

***Recruiting Supervisor, Box 191***

**ARABIAN AMERICAN OIL COMPANY**

**505 Park Avenue** **New York 22, N. Y.**

POSITIONS WANTED

■ SENIOR PROCESS Engineer, broad experience in petroleum refining operations, design, planning, economics. B.Ch.E. Box 251-R, Petroleum Refiner, Houston, Texas.

■ EXECUTIVE ENGINEER, mature, heavy experience petroleum refining, petrochemicals, project engineering, plant design, process development, sales. Fluent German, French, some Spanish. Desires position on management level project engineering, department coordination, sales representation, U. S. or abroad. Replies to Box 250-R, Petroleum Refiner, Houston, Texas.



CLASSIFIED ADS

HELP WANTED

## engineers with purchasing experience for the far east

Large international petroleum company seeks the services of an engineer with purchasing experience to survey Japanese sources of supply for materials used by Company. Initial assignment is Japan but similar duties may be necessary in other Far Eastern countries as well as New York. Family may accompany you. Liberal Company benefits in expanding organization. Salary commensurate with experience. Send complete resumes and salary requirements to

**BOX 254-R**

## SPECIAL PETROLEUM REPRESENTATIVE

Established manufacturer of industrial processing materials has opening for a special representative in the Great Lakes Region.

Applicants must be 25-40 years of age, and must have petroleum refinery experience in the mechanical, engineering, processing, or operations department. 60% travel, salary, plus expenses.

This is an unusual opportunity for a capable man looking for permanency and above average earnings.

Reply giving full details of education, background, and personal status to Box 247-R, PETROLEUM REFINER, Houston, Texas.

HELP WANTED

## REFINING PROCESSES

**based on ADSORPTION and CATALYSIS with MOLECULAR SIEVES**

- removal of normal paraffins from light naptha and reformate.
- catalytic reforming and isomerization.
- sulfur removal from hydrogen and napthas.
- drying and sweetening of natural gas.

We need experienced PETROLEUM CHEMISTS and CHEMICAL ENGINEERS to put the unique properties of Molecular Sieves to work in the Petroleum Industry.
Promising fixed and moving bed cycles under development both in adsorption and catalysis.
Submit resume including education (approximate academic standing), experience and background to:

**LINDE AIR PRODUCTS COMPANY**
a Division of
**UNION CARBIDE AND CARBON CORPORATION**
P. O. BOX 44, TONAWANDA, NEW YORK
Attention: Mr. R. P. Kalle
Refer to Ad: PR-PC

## Mechanical Engineers (Refining)

**(Ages 25 - 38)**

A major integrated U. S. oil company operating in South America has career employment opportunities in the rapidly expanding organization of a large modern refinery for qualified Mechanical Engineers. Vacancies exist in positions at levels requiring 3 to 7 years oil refinery experience or allied industry involving work in (1) process unit design (2) power house design (3) mechanical crafts scheduling (4) shop layout and method studies (5) contract specifications (6) building and construction related to petroleum refining. Salary, including bonus, $13,000-$16,500 depending on qualifications and experience. Excellent employee benefits including home vacations with travel expenses. Send complete resume of personal data and work experience. Replies held in strict confidence and interviews arranged for qualified applicants.

**P. O. Box 480**
**Dept. T-14**
**NEW YORK 19, N. Y.**

## Suppliers . . .

**Thermal Research and Engineering Corp.** of Conshohocken, Pa., has appointed **William Page** as district sales engineer in Cleveland. Thermal manufactures specialized combustion and heat transfer equipment.

**Beckman Instruments** announces that **Thomas V. Parke,** manager of research and engineering, has returned to the Scientific Instruments Division after having addressed the Fourth International Instruments and Measurements Conference in Stockholm, Sweden.

Parke discussed the application of infrared spectroscopy to the development of improved pharmaceutical products to highlight the introduction to northern Europe of Beckman's new infrared spectrophotometer.

**Minnesota Mining & Manufacturing Co.** has appointed **Gordon V. Gorecki** as market development supervisor for 3M reinforced plastic pipe. Gorecki will be responsible for market development, field testing installations and assisting in the development of merchandising programs.

After joining 3M as a junior engineer in the tape laboratory in 1944, Gorecki served as technical service engineer and assistant manager of technical service for tapes. In 1952 he became assistant manager of the industrial trades masking tape division, and for the past year he has served as market supervisor for industrial trades tapes.

# CLASSIFIED ADS

HELP WANTED

OPPORTUNITIES WITH MONSANTO

## CHEMICAL ENGINEERS-CHEMISTS

in

PROCESS INVESTIGATION and PLANT OPERATION

also

## MECHANICAL ENGINEERS

for

MAINTENANCE

Monsanto Chemical Co. has several immediate openings in its Technical Service (Process Investigation) group at the Texas City plant.

These career opportunities offer initial assignments in process studies involving manufacture of monomers and petrochemicals.

Additional openings available in the production dept. to staff new operating units soon to go on stream. Also several openings in the maintenance department for Mechanical Engineers.

Pleasant working conditions in a growing, friendly Gulf Coast City. Excellent schools and recreational facilities.

If you have 0-10 years experience in petrochemical or allied fields and wish to move into a growing company, send a resume of experience with a letter of application to

Manager, Technical Recruiting

**MONSANTO CHEMICAL COMPANY**

**P. O. Box 1311** **Texas City, Texas**

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FOSTER
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Handle more cars better—cost less to install and maintain. Foster stocks all Rail Sections 12# thru 175#, Switch Material and Track Accessories.
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## Suppliers . . .

**Robertshaw-Fulton Controls Co.** will be represented in Montana, northern Idaho and northern Wyoming by **Continental Laboratories, Inc.,** Billings, Mont. Fielden manufactures electronics and electro-mechanical instrumentation for industrial and laboratory applications.

**Delta Tank Manufacturing Co., Inc.,** has appointed **John W. Young** as sales engineer of the oilfield equipment division. Young has been assigned to Delta Tank's Westwego, La., staff.

He previously served as a mud engineer with the National Lead Company's Baroid Division in Bay City, Texas; Chickasha, Okla., and various Canadian oil regions. Young holds an engineering degree from Mississippi State College.

**Anthony Co.,** Streator, Ill., has named **Frank C. McManus** to the post of president. McManus succeeds **Glenn A. Duis,** who resigned in order to devote more time to personal interests.

McManus has had extensive experience in the engineering and management branches of industry allied to the Anthony line of truck equipment. For 20 years he was associated with the Mack Truck Co., both as an engineer and factory manager. He also was identified for several years as division manager with the Fuller Manufacturing Co. of Kalamazoo, Mich.

**Climax Molybdenum Co.** has added **Dr. H. W. Schultze** to its staff as assistant manager of chemical development. In his new position, Dr. Schultze will be responsible for expanding the use of molybdenum catalysts in the process industries and for the development of new chemical applications of molybdenum compounds.

Prior to joining Climax, he was in the product and process development department of the Electro Matallurgical Co., a division of Union Carbide and Carbon Corp.

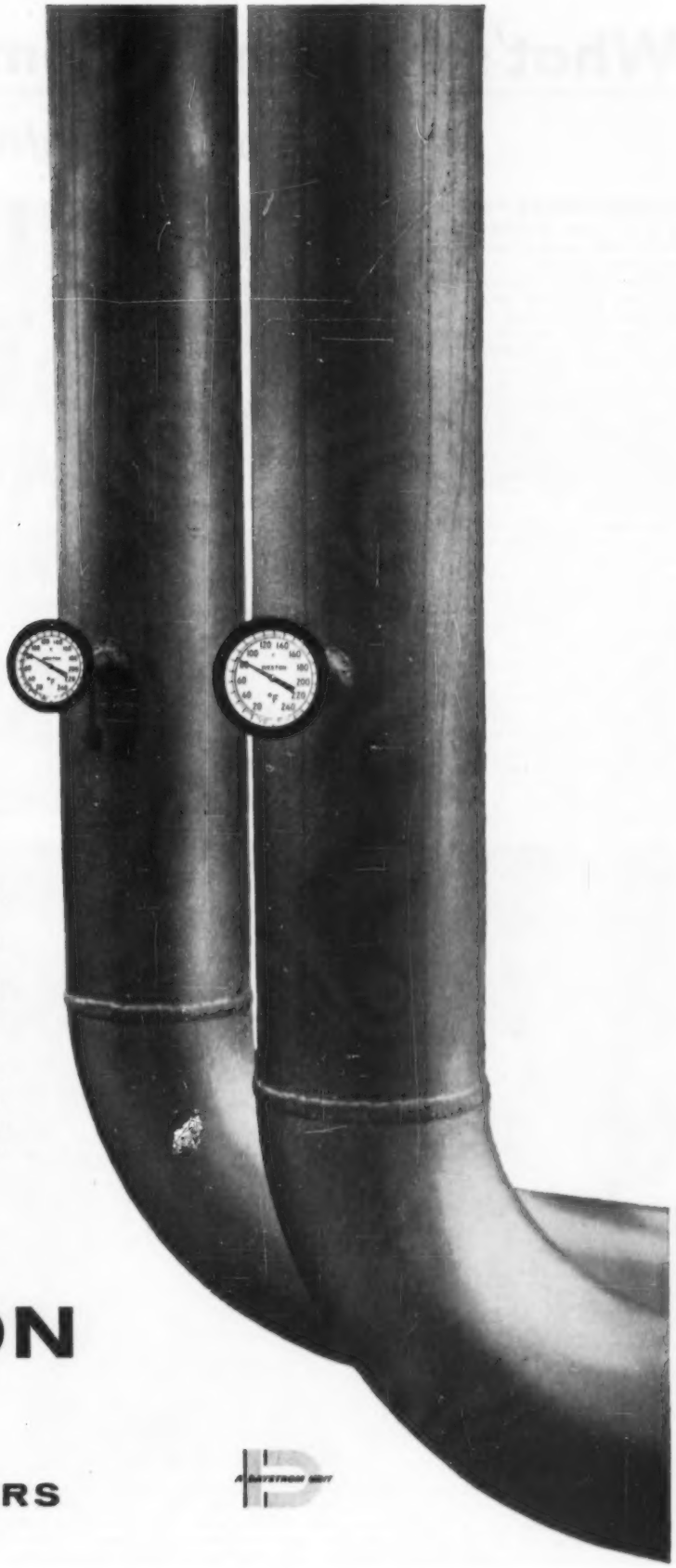
**Allis-Chalmers Manufacturing Co.** has appointed **Charles F. O'Riordan** manager of the Midwest region of Allis-Chalmers Industries Group. He succeeds **J. F. Burrus,** recently named an assistant general manager in the firm's power equipment division.

O'Riordan joined Allis-Chalmers in 1935 after receiving his electrical engineering degree from Virginia Military Institute.

**Joseph M. Duncan,** a sales representative in the New Orleans district since 1951, succeeds O'Riordan as manager at Atlanta. Duncan is a 1949 graduate electrical engineer of Duke University.

**H. K. Porter Co.,** has named **Kenneth M. Wilhelms** superintendent of the Laclede Works, Laclede-Christy Company division.

Wilhelms graduated from Missouri School of Mines and Metallurgy as a ceramic engineer in 1946. He joined Laclede's quality control department and in two years was made factory foreman. He became assistant works superintendent in 1952, a position he held until his recent promotion.



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## *on all counts!*

- **inherently right,** because of Weston's exclusive design and advanced manufacturing techniques
- **easy-to-read right,** because they read with on-the-button accuracy, *at a glance*
- **and right** for budget reasons, because they give trouble-free service for years — bring thermometer costs *'way down*

Weston bimetal thermometers are available in types, sizes and ranges for industrial as well as laboratory needs. Bulletin T13 gladly sent on request. Weston Electrical Instrument Corporation, Newark 5, New Jersey.

# WESTON
## *Bimetal*
## THERMOMETERS



For more data on advertised products, use Readers' Service Cards, last page.

# What's New in Equipment . . .

## . . . and Manufacturers Literature

**Flexible Hose "Switchboard"**—A new system of flexible hose links combined with quick-connect "snap-on" hose couplings (Figure 1) is one of the features of Dow Corning Corporation's new facilities for producing silicone fluids at its Midland, Mich., plant.

Using these snap-on flexible hose links in place of multiple-valve installations, conventional fixed pipe lines are run to a central point where the flexible links can be rapidly shifted from one piping line to another, resulting in a switchboard-like arrangement (Figures 1 and 2). Such "piping switchboards" have begun to appear in chemical, oil refining, and other processing plants, where they meet all requirements for practical application in high-capacity, high-pressure fluid lines.

The patented quick-seal coupling is entirely leakproof at low and high pressure, is free of internal obstructions so as to cause only slight pressure drop in the line, and is practically maintenance-free, requiring only the replacement of seal rings at long intervals. With the "switchboard" system as installed at Dow Corning, any number of processing units can be connected to perform the same operation simultaneously, or material can be sequenced through any desired order of processing operations. It is now possible to design "switchboard" type liquid transfer systems which cost much less to construct, require much less space, and provide many plant operating advantages

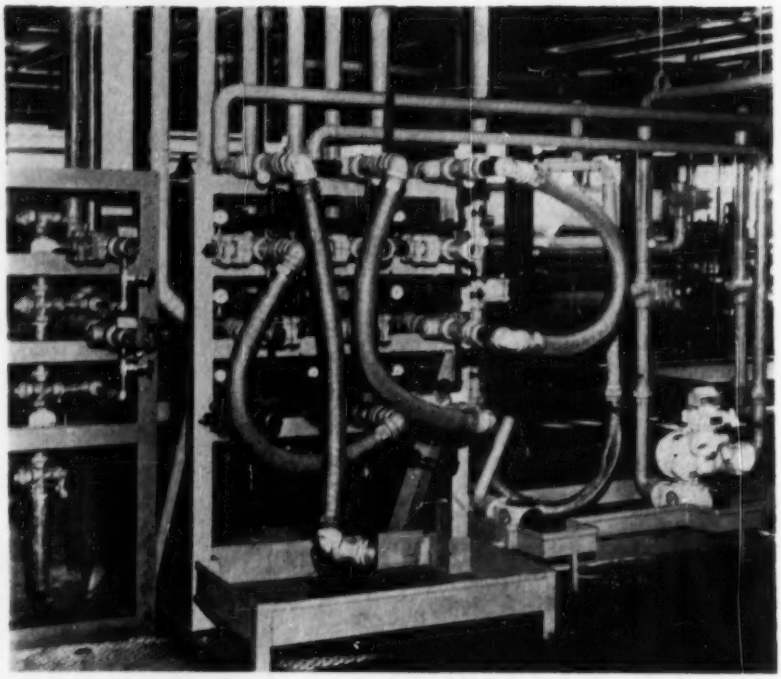


FIGURE 1—Piping switchboard for processing unit battery. Note accessibility of pipe lines for easy connection by flexible connecting hose, also the trough below switchboard to catch drip from disconnected hose.

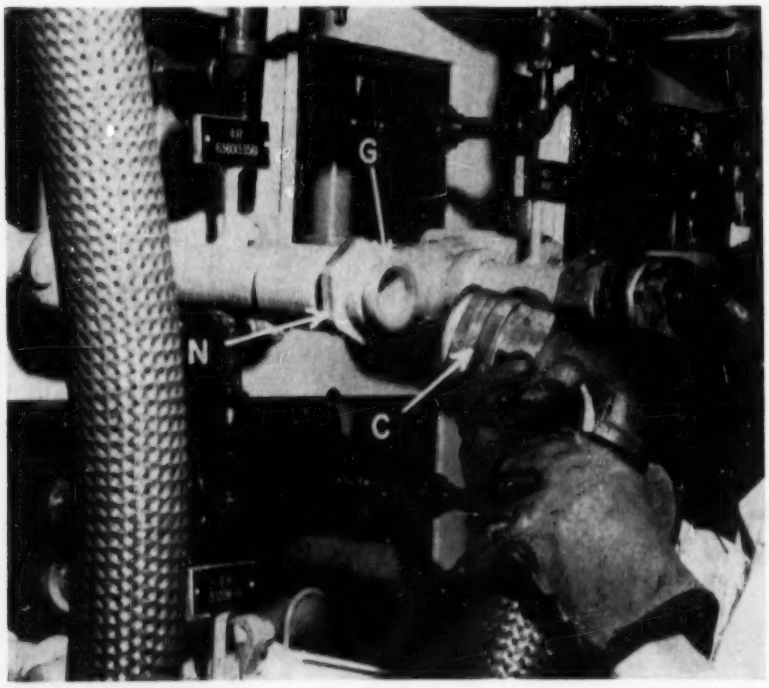



FIGURE 2—Snap-on operation for connecting flexible hose to desired fixed line at piping switchboard. Collar on coupling body (C) is pulled back slightly from forward spring loaded position. This releases retaining balls in coupling body, which can be slipped over the coupling nipple (N) on end of desired line. When collar on coupling body is released, spring snaps it forward and locks retaining balls in groove (G) of nipple, securing coupling and flexible hose to fixed line.

(such as improved safety) over the conventional valve-manifold type of liquid piping systems. Titeflex, Inc.

Circle E1, green card, last page

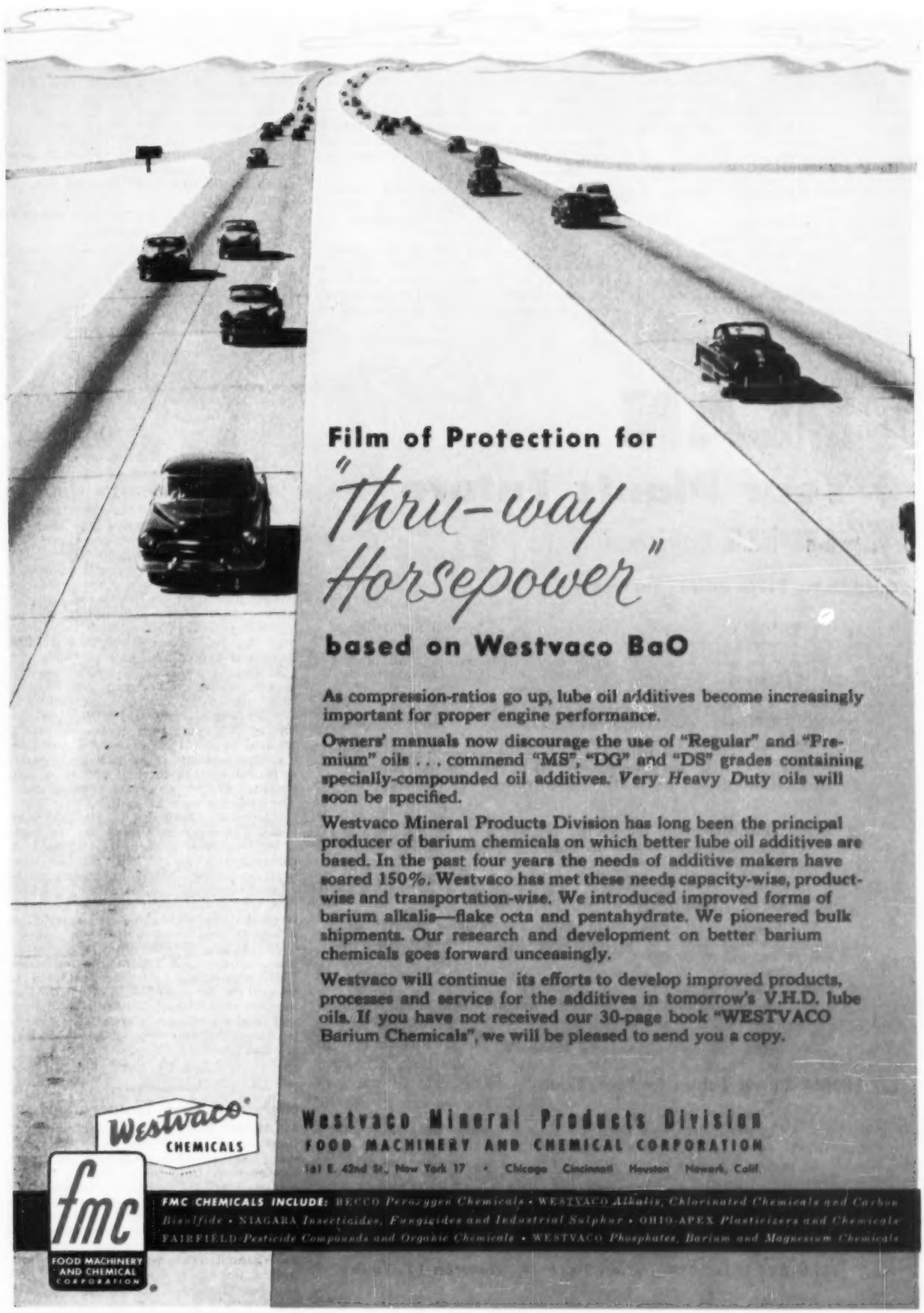
**New equipment is news!**

**It is for this reason that Petroleum Refiner devotes an entire section to the new products and literature presented by various manufacturers to the men of the refining-petrochemical-natural gasoline industry.**

**The equipment items presented in this section have been carefully screened by our New Equipment Editor so that you may keep pace with the new products in this constantly changing industry.**

**Research Facilities Bulletin**—This new 12-page, two-color bulletin describes the research facilities which are now available to industry on a contract basis for the first time in the firm's 66-year history.

Services offered by this experienced out-



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**based on Westvaco BaO**

As compression-ratios go up, lube oil additives become increasingly important for proper engine performance.

Owners' manuals now discourage the use of "Regular" and "Premium" oils . . . commend "MS", "DG" and "DS" grades containing specially-compounded oil additives. *Very Heavy Duty* oils will soon be specified.

Westvaco Mineral Products Division has long been the principal producer of barium chemicals on which better lube oil additives are based. In the past four years the needs of additive makers have soared 150%. Westvaco has met these needs capacity-wise, product-wise and transportation-wise. We introduced improved forms of barium alkalis—flake octa and pentahydrate. We pioneered bulk shipments. Our research and development on better barium chemicals goes forward unceasingly.

Westvaco will continue its efforts to develop improved products, processes and service for the additives in tomorrow's V.H.D. lube oils. If you have not received our 30-page book "WESTVACO Barium Chemicals", we will be pleased to send you a copy.

Westvaco CHEMICALS

**Westvaco Mineral Products Division**
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**FMC CHEMICALS INCLUDE:** BECCO *Peroxygen Chemicals* • WESTVACO *Alkalis, Chlorinated Chemicals and Carbon Bisulfide* • NIAGARA *Insecticides, Fungicides and Industrial Sulphur* • OHIO-APEX *Plasticizers and Chemicals* • FAIRFIELD *Pesticide Compounds and Organic Chemicals* • WESTVACO *Phosphates, Barium and Magnesium Chemicals*

## New Equipment . . .

side research staff are explained, accompanied by case histories of recent research and development projects. Fluor Corp., Ltd. **Circle E2, green card, last page**

**New Welding Electrode**—The development of a new mild steel arc welding electrode, with iron powder coating, has been announced.

Believed to be the first in the E6010 class with iron powder coating, the new electrode, designated the Strikeasy 610 is recommended for use in field construction, including pipelines, ship fabrication, and pressure pipe welding, where high quality deposits are required.

The addition of iron powder to the electrode coating has resulted in greatly improved weld quality, particularly in root passes, because of the reduction in size of the "wagon tracks" usually formed in mild steel welding. As a result of the action of the iron powder, slag offers no interference in confined joints or vertical down welding, and removal from the surface and edges of deposits is easy and complete.

Other applications for the new electrode are fabrication of tanks, fired and unfired pressure vessels, steel casting repair, and welding of machinery parts.

The iron powder coating also gives a more stable arc and improved shielding, which aid in control of the arc, according to the engineers. The fast freezing deposit wets and spreads readily as it is applied, reducing the effort necessary to control undercut and weld shape and size, they said.

Actual test results on the new electrode, obtained in a test plate welded with 3/16-inch diameter, at 175 amperes, d-c reversed, showed a range of 63,900—64,500 psi ultimate, 52,600—53,450 psi yield, 25.5—27.5 percent elongation. Deposit analysis was carbon .04-.09, manganese .30-.50, phosphorus .035 max, sulphur .035 max, and silicon .10-.30. General Electric Corporation.

**Circle E3, green card, last page**


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**1** EXPERIENCE in all phases of chemical, petrochemical and refining engineering.

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For those problems beyond your own engineering staff, you can rely on the experienced Lidell engineers to solve every phase of new engineering projects and developments. Let us show you our particular qualifications to assist you in the development of new ideas and future plans.

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Our process engineering group, through continuing interest and study, is always abreast of the latest developments and new processes, and of the improvements of existing techniques.

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For your preliminary planning, Lidell will prepare detailed reports giving preliminary plans, economic surveys and estimates of engineering and design requirements. Lidell reports are prepared by experts to assure sound and accurate financial evaluation.

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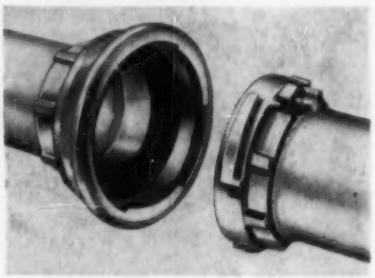


**Industrial Coupler for Portable Pipelines**—The first industrial coupler for portable aluminum pipe lines that will withstand working pressures up to 1000 PSI, and is available both in OD and IPS pipe sizes, has now been developed.

Several tests have shown the new lightweight pipe lines can be moved from six to ten times faster than older types of portable pipe lines. Heretofore there have been no field-proven couplers strong enough to handle such high pressures.

Heavy breach-acting jaws secure the coupler with a quarter turn. A lock screw spins up in an instant and locks the coupler against untwisting through line torque. No metal part of the coupler is exposed to the material within the line; a special aromatic resistant Buna-N gasket is placed so that there is almost no disturbance of flow to create friction losses. The gasket is pressure sealing.

The new coupler can take rough treatment. There are no threads on the body of the coupler to become damaged or clogged with dirt. There are no loose parts to be lost. The coupler protects the ends of the pipes from damage.

A corrosion-resistant alloy is used that is compatible with the pipe material; it is heat treated for strength.

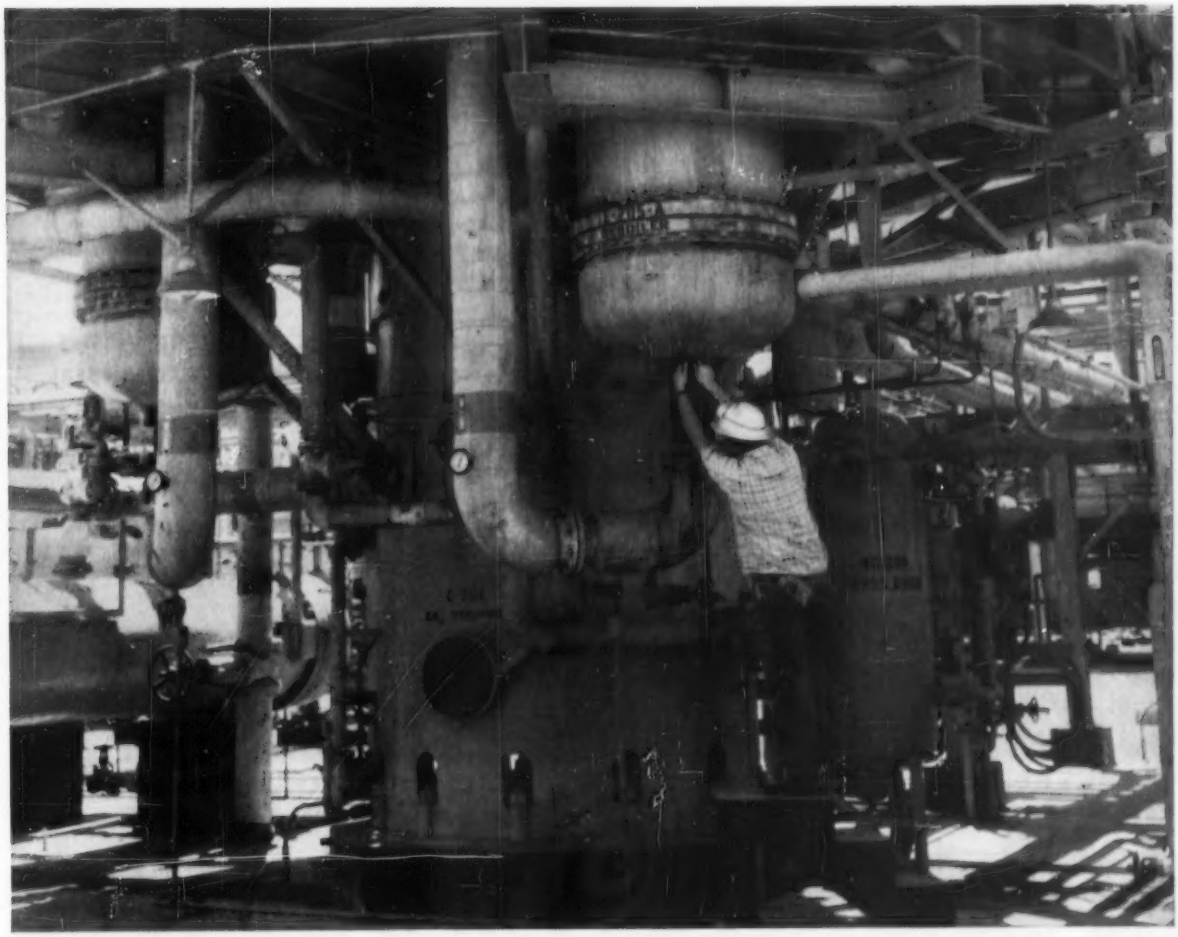
In addition to being used in the petroleum, construction and mining industries, FMC coupler-pipe lines are excepted to be used for the transmission of corrosive or abrasive materials, as well as sticky liquids and semi-solids, since the lines can easily be dismantled and cleaned. Food Machinery and Chemical Corporation.

**Circle E4, green card, last page**

**High and Low Temperature Insulation**—Engineers and others involved in the insulation of pipe and vessels carrying medium or high pressure steam at temperatures from up to 600 F. will be interested in the helpful information offered in the six page bulletin #401 on the new product line of 85 percent Magnesia Pipe Covering and Block Insulation. Lightweight, high compressive strength, low thermal conductivity and closely controlled uniformity are combined in this new product line. With the use of "nesting" outside diameter dimensions, these



For more data on advertising products, use Readers' Service Cards, last page.



**Monel-protected** . . . Reboilers on this column used for stripping $CO_2$ from monoethanolamine solutions at a Shell Chemical anhydrous ammonia plant contain Monel alloy tubes. Tubes have shown no significant corrosion in two years.

# Little to do but turn the valves when MEA reboilers have Monel bundles

## Shell Chemical checks $CO_2$ corrosion . . . descales only once in two years

This workman never had it so good.

Used to spend a good deal of time with the two reboilers on this column which strips $CO_2$ from "fat" monoethanolamine solutions. First he would dismantle one. Descale. Hook up again. Before long it was the other's turn. Every three to six months new tubes had to go in.

**But that all stopped in 1954**

Shell Chemical put in Monel* nickel-copper alloy tube bundles.

Since then, the reboilers have been descaled but once. What's more, deposits appear to contain no corrosion products . . . just stream precipitates. Tubes look like new . . . have never been replaced.

**Take a leaf out of Shell Chemical's book**

Inco's Corrosion Engineering Section will be glad to help you check into corrosive conditions within your MEA reboilers.

If Monel alloy is indicated for the tubes . . . and there's a good chance that it will be . . . put it in!

Then relax. Look at the meters. Turn a valve once in a while.

*Registered trademark

**The International Nickel Company, Inc.**
67 Wall Street New York 5, N. Y.

INCO Nickel Alloys

# Monel . . . *for minimum maintenance*



For more data on advertised products, use Readers' Service Cards, last page.

## CENTRIFUGAL SYNTHESIS GAS CIRCULATORS

GHH Maulwurf pumps are high pressure centrifugal gas circulators especially designed for application in the chemical industry to increase the pressure of the nitrogen-hydrogen mixture in ammonia synthesis.

COMPRESSORS
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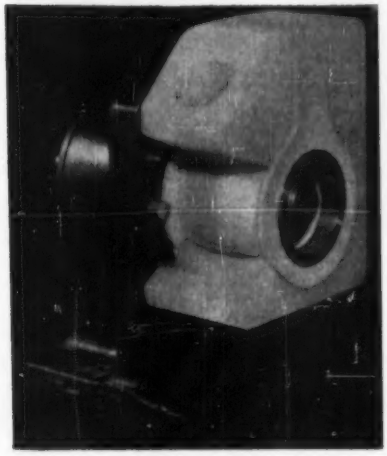
## New Equipment . . .

coverings can be applied in multiple layers in exact telescopic fits.

Also available is a four pape bulletin #400 furnishing specifications, recommended thicknesses, sizes, and other details on the other new product line of HYLO Pipe Covering and Block Insulation to serve a complete range of temperatures from a high of 1600 F. to a low of 100 F. It is an accurately molded product made from inorganic silicas and it exhibits no deterioration or effect on thermal conductivity after exposure to high moisture conditions. HYLO can be used in single layer applications or as a base layer with the 85 percent Magnesia where temperatures will exceed 600 F. For ease of application HYLO is furnished in pipe covering in three foot sections, flat, curved or segmental blocks. Eagle-Picher Co.

**Circle E5, green card, last page**



**New Corrosive Fluid Pump**—A new pump wherein fluids handled are in contact only with Teflon or Kel-F. The pump is designed for use with many extremely corrosive fluids, including those which could not be handled previously with other plastic or stainless steel materials of construction.

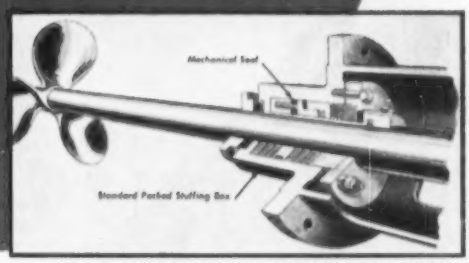
Since shaft seals and stuffing boxes are eliminated in the Vanton pump design, fluids or slurries are wholly isolated in a passage formed by the outer surface of the Kel-F liner and the inner surface of the Teflon or Kel-F body block. Operation of the pump is by means of an eccentric shaft and rotor assembly rotating within the liner and progressively pushing the fluid about its outer surface.

Teflon and Kel-F fluorocarbon materials have excellent resistance to temperatures up to 300° and corrosive fluids which include strong oxidizing acids, mineral acids, alkalies, aliphatic solvents and a number of chlorinated solvents as well as various types of fuels, hydraulic fluids and red fuming nitric acid. Vanton Pump & Equipment Corporation.

**Circle E6, green card, last page**

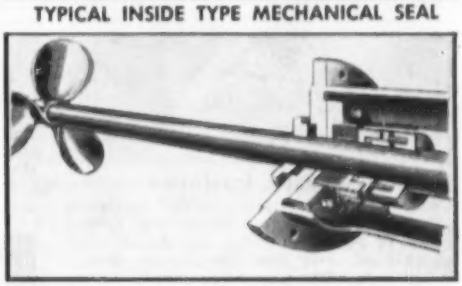
**Brochure Describes Model Supplies**—The tremendous increase in the use of scale models in the past few years, and their acceptance as a valuable engineering tool, has encouraged many en-


NOW! International AGITATORS With Mechanical Seals




TYPICAL INSIDE TYPE MECHANICAL SEAL

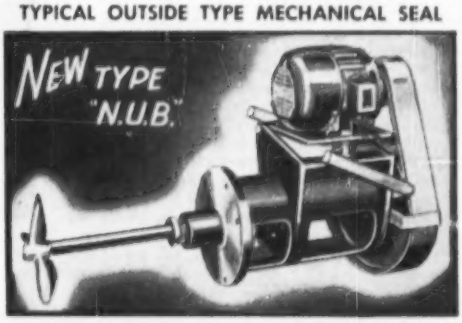
Specifically designed to resist corrosion, high temperatures and pressures —to seal toxic or flammable fluids perfectly without losses,—to reduce fire hazard, power, labor and repair costs, with much longer service and fewer shut downs. Certain applications show reduction of friction up to 83% over conventional packings— No scoring of shafts—permits specially designed sealing of gritty and abrasive fluids.



TYPICAL OUTSIDE TYPE MECHANICAL SEAL

**New "International" Mechanical Seals**

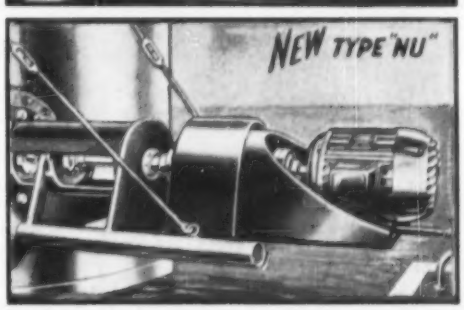
INTERNATIONAL can furnish either standard packed Stuffing Box or Mechanical Seals.—On Side Entering Mixers either Seal can readily be converted to the other, if desired, as shown in upper right hand illustration.




SHUT-OFF CONNECTION on side entering mixers allows repacking or replacement with either standard Stuffing Box or Mechanical Seals with a full head of liquid, without appreciable leakage.

**Technical Bulletins Available**

INTERNATIONAL stands back of its product with expert engineering service help when you need it. Over a Quarter Century of complete coverage in Petroleum Agitation—Remember to investigate "INTERNATIONAL" when you want prompt action and Guaranteed performance—Ask for Special Bulletins on Top Entering, Side Entering and Portable Mixers today.




**INTERNATIONAL ENGINEERING, INC.**
**DAYTON 1, OHIO**

NEW YORK 15 Park Row WO-rth 2-2580
CHICAGO 3454 W. Lake Street Sacramento 2-6750

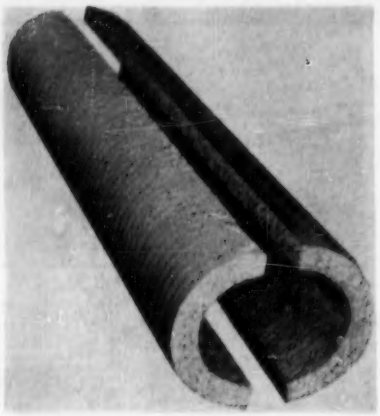



For more data on advertising products, use Readers' Service Cards, last page.

## New Equipment . . .

gineering firms to establish their own model making facilities. Many others are considering the possibility of such a move.

This brochure describes the various scale models of items used in refineries and petrochemical plants. These items include valves, fittings, saddles, vessel heads, railings, structural shapes and other model making tools. Engineering Model Associates. **Circle E7, green card, last page**



**New Type Pipe Insulation**—A new wide temperature range molded insulation designed for use on steam and heated process piping has been introduced. This highly effective low conductivity insulation withstands pipe temperatures up to 1350°.

Kaytherm, which is produced in half-cylindrical sections and segments 36 inches long, is easy to install requiring only simple encircling metal bands to fasten two mating sections to a pipe. It can be cut and worked with ordinary tools. This pipe insulation comes in a variety of thicknesses ranging from one-inch to four inches and will accommodate pipes up to 33 inches in diameter.

Kaytherm pipe insulation is made by reacting lime and diatomaceous earth under suitable conditions of heat and water to form a hydrous calcium silicate which is bonded together with asbestos fibers. This chemically stable insulating material has many of the favorable characteristics of fine concrete such as strength, wear resistance and unusual dimensional stability.

The largest produced sections of Kaytherm are light in weight and easy to handle. Kaytherm is flame-resistant and chemically inert and insoluble in water. Its compressive strength permits it to be laid over any irregular shapes, bolts, and depressions and held tight without concern of breakage. Keasbey & Mattison **Circle E8, green card, last page**

**New Delivery Date Calculator**—The company has just produced a handy new gadget which they call the "Delivery Date Calculator."

Produced on heavy-weight varnished board, the disc-type gadget determines the future date immediately. The user simply sets arrow opposite date of order and gets direct reading of estimated delivery date. Free on request. Nooter Corporation.

**Circle E9, green card, last page**

**Rotary Toggle Switch**—A new rotary toggle switch that offers a solution to the problem of controlling many circuits with single-motion, mechanical actuation has been introduced.

The small switch can handle a high electrical load, thus eliminating the use of relays and other electrical devices. It is rugged enough for most industrial and airborne applications, having successfully passed impact, shock, acceleration and vibration tests.

The four-pole, double-throw switch (designated 4TR1) is maintained in all three actuation positions: on-off-on. It has 12 terminals. Other models are available with up to 24 terminals (8 poles).

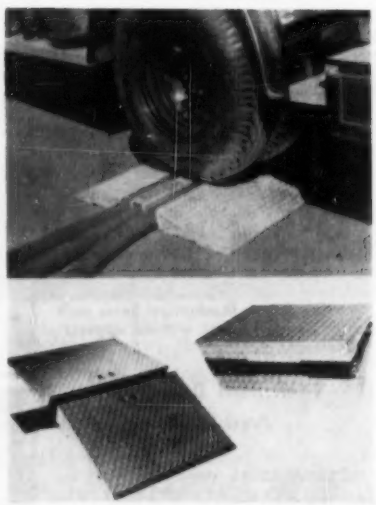
The switch has an operating force of 9-inch pounds max. Electrical rating is as follows: Continuous capacity of 30 volts d-c; 20 amps resistive; 5 amp lamp or 12 amps inductive. At 115 volts a-c, 20 amp resistive; 4 amp lamp and 15 amps inductive. Minneapolis-Honeywell. Regulator Company.

**Circle E10, green card, last page**

**New Type Aluminizing Process**—The process is applicable to any ferrous-base alloy and produces a tighty adherent coating resistant to $H_2S$ and $H_2$-$H_2S$ corrosion in furnace tubes and process lines in oil refinery service, particularly in reforming units.

This process which is described in a new technical data sheet permits the use of low-cost ferritic alloy steels instead of the more expensive austenitic stainless steels, for severely corrosive applications. Chicago Metallizing Corporation.

**Circle E11, green card, last page**



**Portable Ramps Make Roadway Over Hoses**—Here is the anwer to stopped traffic or emergency "corduroy" roads because of flexible hoses on the ground. New, portable hose ramps make a smooth roadway for traffic to pass over fire hoses, fuel lines, air hoses, etc., up to 4 inches in diameter. Each ramp is made of lightweight magnesium (36 inches long, 16 inches wide, weight 20 pounds) and constructed to give rigid support of 10,000 pounds. (Also available up to 40,000 pounds support each.) Diamond safety tread provides good traction in all weather.

Pairs of ramps are held together by heavy neoprene belting to give flexibility on rough terrain and allow sections to fold for easy storage.

Special ramp extenders (filler strips) make a longer roadway when multiple hoses must be crossed.

Portable hose ramps are useful in both emergency and regular work use. Easily stacked and carried, they are especially valuable in mining and petroleum work where flexible lines are often thrown across roads or work areas. The quick, portable roadway allows regular traffic to proceed or supply vehicles to move around. Copperloy Corporation.

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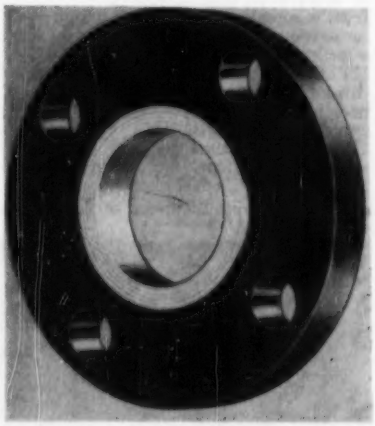
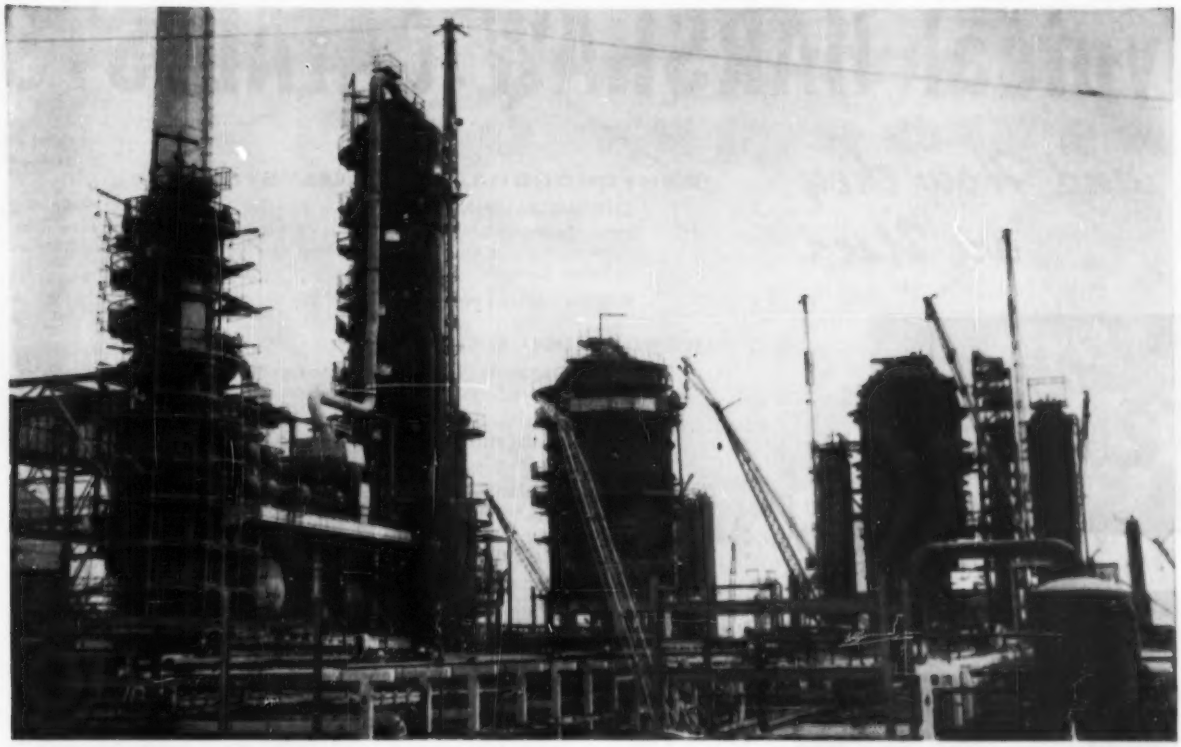


**Improved Insert Flange**—A recently improved type of insert flange has been developed for use with process piping. These insert flanges are a bi-metal product. The inserts are of stainless steel, or other corrosion resistant alloys, and the flanges are made of carbon steel, so that when assembled and placed in use, only the insert comes in contact with the corrosive element. The flanges make a rigid connection with true machine concentric grooves on gasket face to insure maximum sealing for leak-proof joints. They allow a flexibility and ease of installation, maintenance and replacement no other flanges provide, they eliminate the problem of bolt hole alignment, and they lower labor costs on original and replacement installations wherever used. Available types are slip-on insert flanges, said to be easiest welded of all slip-on flanges; roll-on insert flanges, for low cost assembly by using a simple expanding tool; socket type insert flanges, that are self-aligning and permit better and faster welding; thread-on insert flanges that are easily used with other screwed pipe and fittings. The insert flanges are available in types 304 and 316 stainless steels and in sizes from ½-inch IPS to 6-inch IPS, for use with schedules 5, 10 and 40 pipe. Larger sizes up to 12-inch IPS, other alloys and in the 300-pound and 600-pound series flanges are also available upon application. Stainless Insert Flange Company.

**Circle E13, green card, last page**

**Fluid Teflon Used as Thread-Sealer**—The use of fluid Teflon as a thread-sealing and antiseize compound for metal, plastic, carbon and ceramic systems and equipment, is described in this new bulletin. Included are typical applications for fluid Teflon, designated as Eco T-film, in the chemical, petroleum, and process equipment industries.

A discussion of T-film threaded joints points out the advantages and cost savings to be gained as compared to the use of



**A dozen vessels built by Newport News** were furnished under contract with C. F. Braun, Inc., of Alhambra, Calif., design engineers for the ultra-modern Delaware Flying A Refinery of the Tidewater Oil Company located 15 miles south of Wilmington.

# Newport News builds 12 major components for new Flying A 130,000-bpd refinery

This is the new Tidewater Delaware Flying A Refinery now under construction near Wilmington.

Newport News fabricated 12 of its major vessels — 2 of which are the largest such units ever built: a 250′ Orthoflow fluid "cat cracker" converter and a 225′ reactor scrubber of the fluid coker.

More notable than size, though, is the quality of the Newport News fabrication.

Coke-out screens in the reactor scrubber, for example, are made of 704 12% chromium segments. Welded together with accuracy, they provide 45% clear opening . . . with opening tolerances less than 1%.

You get expert fabrication, the skill of specialists when Newport News builds your equipment. When you want reactors, pressure vessels, vacuum tanks and the like, sub assemblies or weldments in almost any size or shape, get a bid from Newport News.

Send for newly published, easy-to-read, illustrated booklet, "Facilities and Products". It describes the many ways in which Newport News can help you with present or future projects. Write for your copy today.

**Full advantage** was taken of the Newport News deep water loading facilities for transportation of all of the equipment by barge. Shop erection prior to shipment assured fast, trouble-free field assembly.

**Engineers:** Desirable positions available at Newport News for Designers and Engineers in many categories. Address inquiries to Employment Manager.

**Newport News** Shipbuilding and Dry Dock Company, Newport News, Virginia

# Typical HARSHAW CATALYSTS

## *and How they are Used*

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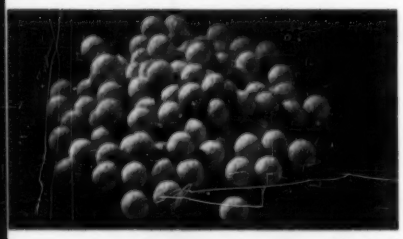
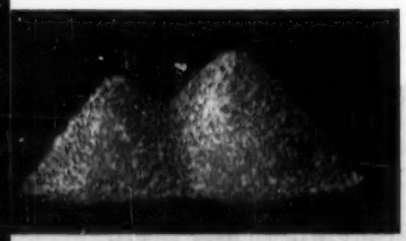


SPHERICAL

GRANULAR



POWDERED

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**"HARSHAW CATALYSTS"**

### DEHYDROGENATION CATALYSTS

**CHROME-ALUMINA**—available in powder or tablet form containing various percentages of chromium oxide supported on high surface area alumina—can be supplied as promoted catalyst and is also available as screened granules.

**IRON**—tableted iron oxide.

### REFORMING CATALYSTS

**MOLYBDENA-ALUMINA**—supported molybdenum oxide on alumina—available as microspheres for fluid techniques, or as tablets for fixed bed application.

**COBALT MOLYBDATE**—a supported cobalt oxide—molybdenum oxide catalyst supplied in tablet form.

**NICKEL-ALUMINA**—a spherical catalyst available as hard spheres measuring ¼″ to 1″ diameter—used for some types of gas reforming.

### DESULFURIZATION CATALYSTS

**COBALT MOLYBDATE**—a supported cobalt oxide—molybdenum oxide catalyst supplied in tablet form.

**ZINC OXIDE**—a pelleted zinc catalyst used in the desulfurization of natural gas.

**MOLYBDENUM SULFIDE**—powdered and tableted molybdenum sulphide.

### CHLORINATION CATALYST

**COPPER**—supported copper catalyst prepared and shipped as tablets or granules.

### HYDROGENATION CATALYSTS

**NICKEL-KIESELGUHR**—supplied as unreduced, or reduced and stabilized, tablets, ⅛″ to ⅝″ diameter.

**NICKEL-ALUMINA**—available in tablet form containing nickel as nickel oxide on high surface area alumina, or in spherical form supported on low area, high-fired alumina.

**RUFERT FLAKES**—reduced nickel protected by hardened oil shipped as free-flowing flakes for hydrogenation of all glyceride and acid fats.

**COPPER-CHROMIUM OXIDE**—shipped as powder or tablets, stabilized or non-stabilized, with varying ratios of copper oxide to chromium oxide.

**NICKEL-ALUMINUM**—powdered 50:50 alloy used for preparation of active nickel catalyst for low temperature hydrogenation.

### CATALYSTS FOR ORGANIC SYNTHESES

**ZINC CHROME**—a tableted zinc oxide—chromium oxide catalyst used in the synthesis of methanol.

**MERCURIC CHLORIDE**—a granular catalyst consisting of mercuric chloride on active, granular carbon used in the synthesis of vinyl chloride monomer.

**COBALT THORIA**—available as powder or tablets, a thoria promoted cobalt catalyst employed in Fischer-Tropsch synthesis.

**COBALT**—a supported cobalt catalyst in pellet form used in the synthesis of hydrogen sulfide.

### DEHYDRATION CATALYST

**ALUMINA**—powdered and tableted aluminum oxide supplied as an active, intermediate surface area catalyst.

Whether your requirement is measured in tons or pounds Harshaw can produce your catalyst exactly to your specifications of raw materials, chemical composition, and physical properties such as length, diameter, crushing strength, abrasion resistance, and bulk density. AND, make delivery when you want it. Call on Harshaw today—for further information or technical assistance.

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Philadelphia 48, Pa. • Pittsburgh 32, Pa.

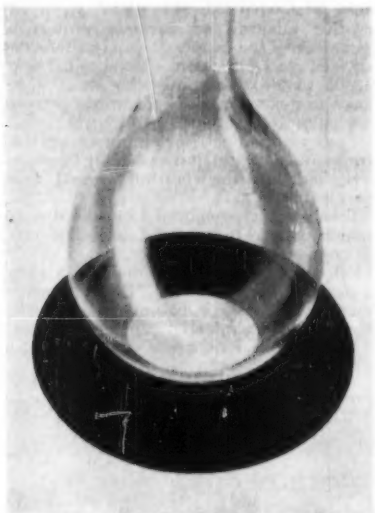
## New Equipment . . .

flanged fittings and weldments in many types of installations. How T-film should be used and applied is also described. Eco Engineering Co.

**Circle E14, green card, last page**

**Valve Bulletin**—Users of shut-off and quick opening valves will be interested in this new bulletin just released. It describes the operation and application of these valves with diagrams illustrating the working parts. Coppus Engineering Corp.

**Circle E15, green card, last page**



**New Flask Support**—Here's a new way to put down a hot round-bottom flask. The answer is on neoprene. These new neoprene flask supports, unlike traditional cork, have an outstandingly long life—even after prolonged exposure to heat.

The new rings simplify storing, too. A bottom ridge on each ring interlocks with the top of the ring under it; a stack stays in place on the shelf. (Even tossed in the "miscellaneous drawer," they're better—won't crack, split or crumble.)

Another advantage is that the new rings don't slip on bench tops, wet or dry. Finally, the shock-resistant qualities of neoprene makes the rings ideal when stirrers or vibrators are used with the flask.

The rings have 5-inch diameters, are beveled to hold either a 250-ml or 500-ml flask. They also offer tip-proof insurance for large (up to 385-ml) evaporating dishes. Fisher Scientific Company.

**Circle E16, green card, last page**

**Index of Instrumentation**—The Bulletin G-2 is an index of Industrial Division literature. It covers catalogs, bulletins, specification sheets, data sheets, illustrated lectures and articles from Instrumentation Magazine. Minneapolis-Honeywell Regulator Company.

**Circle E17, green card, last page**

**Organic Chemical Booklet**—More than 335 organic chemicals are described in a new 24-page booklet just issued. Condensed data on applications are presented and physical properties are given in tabular form. An alphabetical index is included


# PACKAGED TOWER POWER

"Power comes in one piece" on a Marley cooling tower—a completely integrated unit that consists of motor, drive shaft, couplings, Geareducer* and fan hub, assembled and permanently aligned on a rugged unitized steel support.

Every component of this packaged power unit (except the motor of your choice) is Marley-designed and manufactured exclusively and specifically for cooling tower use. Each is engineered for individual mechanical excellence and for functional integration into the complete assembly. All are backed by a single responsibility for dependable performance and economical maintenance, and that backing is the Marley guarantee.

These units are standard for all Marley industrial towers and, together with Marley multi-blade aluminum fans, are available for modernization of towers of any make. Installing the pre-assembled Marley power package for replacement service reduces shutdown time by days.

For detailed information on "packaged power" for new or existing towers, call the Marley sales engineer in any of 55 major cities.

MARLEY **The Marley Company**

Kansas City, Missouri

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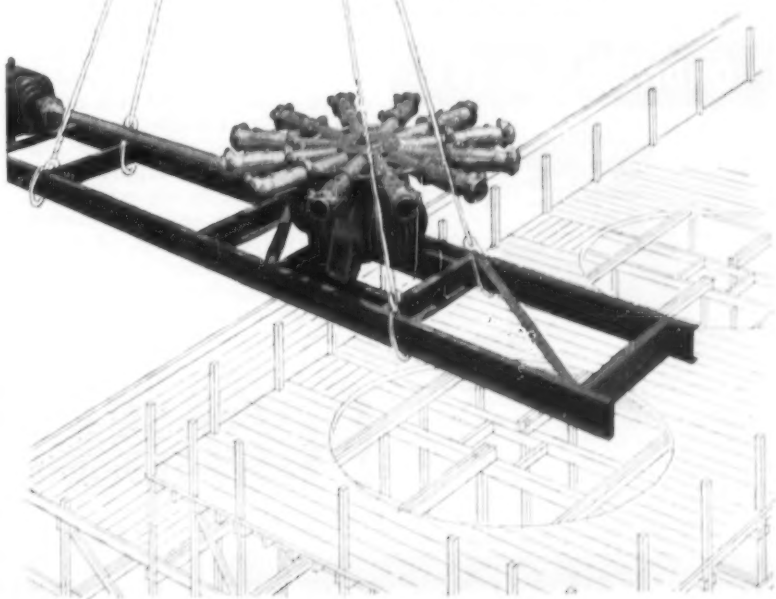




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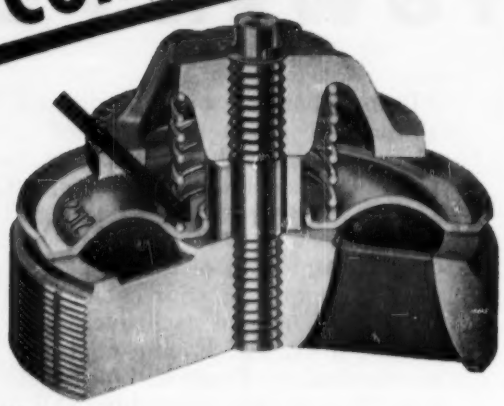
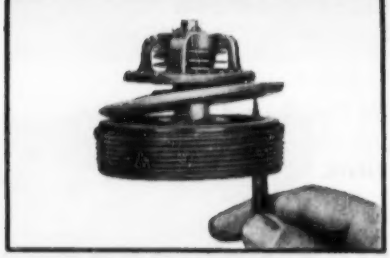
# HOW "POINT CONTACT"



## opens the way to pump valve efficiency

**DURABLA VALVE**



Apply pressure to the outside edge of the valve member with a pencil point. Notice how it tilts and opens with a light pressure, without noticeable friction.

**ORDINARY VALVE**

Now try this with an ordinary valve. If the valve opens at all, it will only open part of the way, and with excessive friction.

All reciprocating pump valves are subjected to flow forces which necessitate tilting of the valve member while opening. In applying pressure through the seat with a pencil point to the outer edge of the valve member you approximate operating action.

In a DURABLA Valve only "point contact" is made by the valve member on the stud or sleeve, so it cannot bind or hang-up on the guard stem, but opens with a tilt-action following the flow line. Other types of valves using wings for seat guiding or high hubs for stem guiding, cannot avoid creating excessive wear and friction, with resultant warpage and possible breakage of valve or stud.

The unique DURABLA Stainless Steel Valve will operate freely under extremes of high or low temperature, with highly corrosive fluids, and in any position. It will handle vacuums of one micron or discharge pressures of thousands of pounds per square inch. Standard equipment on many pumps, it will fit ANY pump, old or new. Ask for bulletin PR-126.

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## New Equipment . . .

for the convenience of the user.

The 1957 edition of "Physical Properties of Carbide and Carbon Chemicals" features twenty-one new products. Sorbic, a fungistat for foods, and Niatex antistatic AG-2 are two of the new products described in the section on chemicals for special applications. For easy reference, other chemicals are arranged by family groups. Carbide and Carbon Chemicals.

**Circle E18, green card, last page**

**New Minerals Protect Against Loss of Catalyst**—The development of sorptive minerals to perform protective "guard duty" on platinum catalyst reforming feed stocks has been announced. These special materials are available in a wide range to meet the needs of various process systems and conditions.

The pre-treating step protects against losses caused by catalyst poisoning by effectively reducing the constituents that foul the catalyst.

Troublemakers removed from the stream include arsenic, tetraethyl lead, alkyl sulfur compounds, and nitrogen.

Full information is contained in a new 12-page technical bulletin, "Preparation of Petroleum Feeds For Platinum Catalysts." Minerals & Chemicals Corp. of America.

**Circle E19, green card, last page**

**Explosion-Proof Hand Lamp**—For safe yet practical lighting in flammable atmospheres, as in the interiors of fuel tanks during cleaning or painting operations, a new portable hand lamp has been introduced. Weighing less than 11 pounds, the new fixture (type EVH70) uses 150-watt PAR-38 reflector type spot and flood lamps, which produce a concentrated light pattern. The fixture is UL-approved for Class I, Group C locations (atmospheres laden with flammable mixtures of ethyl-ether vapors, ethylene, or cyclo-propane) or Group D locations (atmospheres containing hazardous quantities of gasoline, hexane, naphtha, benzine, butane, propane, alcohol, acetone, benzol, lacquer solvent

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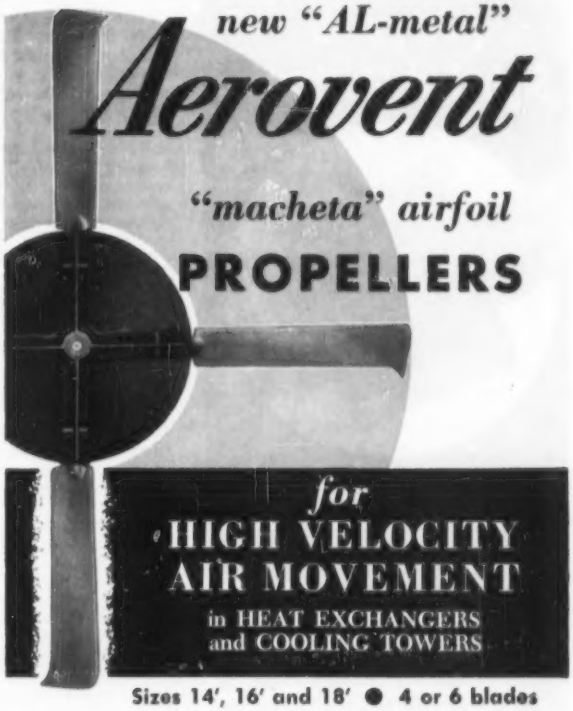
**PROPELLERS**



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in HEAT EXCHANGERS and COOLING TOWERS

**Sizes 14', 16' and 18' ● 4 or 6 blades**

New Aerovent "AL-metal" Propellers for Cooling Towers, Heat Exchangers and special commercial and industrial applications, feature a new modification of the famous "Macheta" Airfoil Propeller – regarded for years as *industry's most efficient air-moving surface!*

Accurately-balanced, cast aluminum blades, designed to move *more* air with *lower* power consumption, are interchangeable with other blades in each assembly to speed and simplify installation and routine maintenance.

High-strength, cast steel alloy hubs, employing bolted construction, clamp keyed blade shanks securely to prevent loosening or turning; provide maximum resistance to vibration and operating stresses.

***designed for* DEPENDABLE *operation***

Endurance tests at *3 times* normal loading prove the ability of new Aerovent "AL-metal" Propellers to withstand punishment far in excess of operating requirements.

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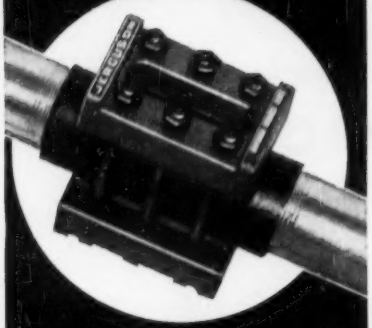
# NEW . . .
## Jerguson Sight Flow Indicators



*easily and inexpensively installed to show movement of liquid in pipe lines*

**Here is a new line of Sight Flow Indicators . . . easily and inexpensively installed in any new or existing pipe line ½" to 2" N.P.T.**

The special design of these new indicators results in a turbulence in the flow of liquid, making it easily visible. Several types of indicating vanes, installed within the chamber, may also be furnished, according to variable conditions of rate of flow and viscosity of liquid. For indication of minute flows, small Sight Flow Indicators with a rotating vertical rising ball are available.

Jerguson Sight Flow Indicators are soundly designed, carefully made, and are backed up by a company with over 40 years experience in the field. Available in Transparent and Reflex types, in a wide variety of materials and linings, and with Wedge Type Illuminators, Haveg Chambers, Non-Frosting Glasses, or other special construction.

*If you have a problem of viewing the flow of liquid in a pipe line, it will pay you to investigate the new Jerguson Sight Flow Indicators today. Send us your requirements or write for Data Unit.*

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Pétrole Service, Paris, France


## New Equipment . . .

vapors, or natural gas).

The fixture's cone-shaped aluminum body is ridged with heat-dissipating fins. Its plastic coated fiber handle, located at the balance point for easy carrying, remains cool even after the lamp has been in use for long periods.

The terminal housing, equipped with a cord clamp with tapered watertight rubber bushing, encloses three pressure connector terminals. For areas where moisture is prevalent, a special version of the EVH fixture is equipped with O-ring gaskets at the relamping joint and terminal housing.

Relamping is accomplished by removing the threaded cover, guard, and lens assembly, then replacing the lamp. The lens is not disturbed during these operations, since it is an integral part of the cover assembly, Crousse-Hinds Company.

**Circle E20, green card, last page**

**Electronic Rating of Heat Exchangers**—The fall issue of a new review features a descriptive article on thermal rating of heat exchangers by electronic computer, together with sections on three types of power.

The five-page rating article is illustrated by rating-flow and correction-factor diagrams and a reproduction of an actual rating sheet.

The power sections of the 28-page review include an article on the company's new nuclear Criticality Facility—a zero-power reactor experimental installation at Schenectady, and separate sections on a power generating plant at Cheshire, Ohio, and an incinerator plant at Oyster Bay, N. Y. ALCO Products, Inc.

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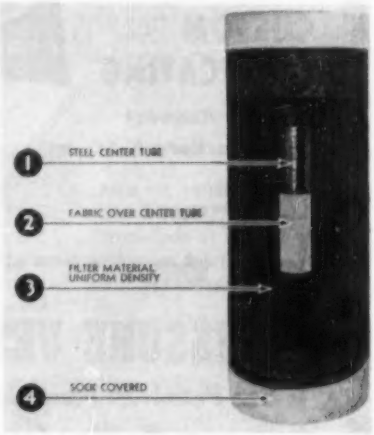


**New Filter Cartridge**—A new filter material consisting of graded cotton fibers felted into sheets and impregnated with a thermo-setting plastic resin, which is not soluble in oil or water, makes these filter cartridges suitable for filtering these liquids.

These cartridges are designed for high flow rate and low pressure drop and removing particle sizes down to 5 microns. They are made in a rigid assembly to avoid sagging and shrinking, and are suitable for fine filtration of all types of lubricating, fuel and industrial oils, and many


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| Zn | .01% maximum |
| Copper Oxychloride—less than | .50% maximum |

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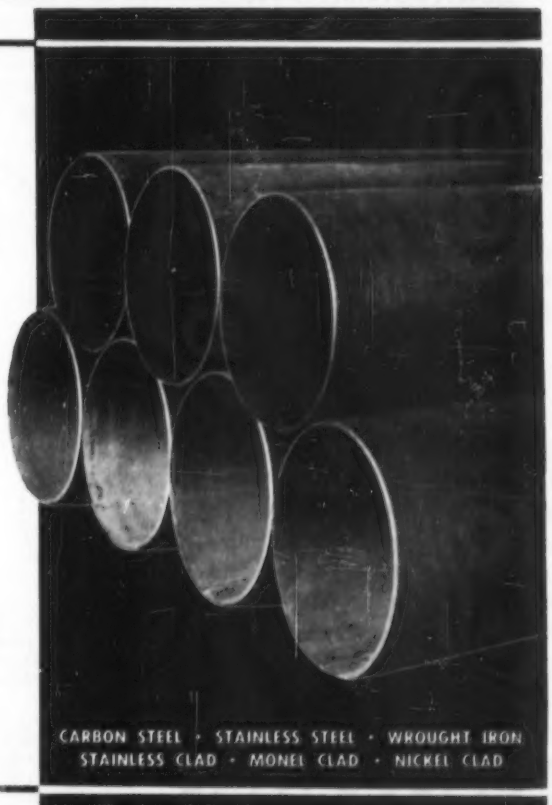

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**TEFLON AND KEL-F INCREASE RANGE OF VANTON PUMPS**

The recent addition of a Kel-F liner and now a Teflon or Kel-F housing to existing materials of the Vanton pump has increased greatly their range of corrosive service.

Designed without shaft seals or stuffing boxes, the pump furnished with these new materials has excellent resistance to most corrosives at temperatures up to 300°F.

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For the full story of how Cooper Alloy Shellcasting knowledge may mean higher quality castings for you, write for Bulletin AKH#5.

**PLUG COCKS WITH V2B CUT GALLING**

Cooper Alloy's V2B keys used in their stainless steel plug cocks have cut down the problem of galling to a very great extent. The September issue of Newscast tells how this helped a tank car manufacturer out of an expensive problem.

COOPER ALLOY
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## New Equipment . . .

aqueous solutions such as coolant compounds.

Bulletin F-152-2 is available describing the filter cartridge more in detail, along with other literature showing the use of the cartridges within filter casings of various designs. The Hilliard Corporation.

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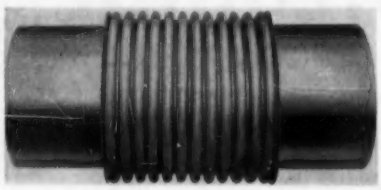

External side view of the new expansion joint.

**New Type Expansion Joint**—After more than three years of research and testing, the company is now offering a redesigned line of packless corrugated expansion joints for use in power, heating, industrial and process piping applications.

The joints incorporate the first basic expansion joint design changes to be made in recent years and are available in several types which are classified in series according to the pressure-temperature conditions to be encountered in much the same way that pipe flanges are rated by the ASA. Thus, joints in series 50 are for lower line pressures while joints in series 150 and higher are for higher pressures.

The most notable design change is in the shape of the corrugations which form the flexing member.

The different design (Figure 1) is based on a correlation among height, shape and pitch dimension which was established as a result of testing corrugation shapes. The new shape gives each corrugation a more effective height which results in greater flexibility and therefore more uniform movement per corrugation. The new corrugation naturally assumes an all-curve shape (dotted line Figure 1) under operating pressures and temperatures and actually "breathes" with pressure fluctuations.

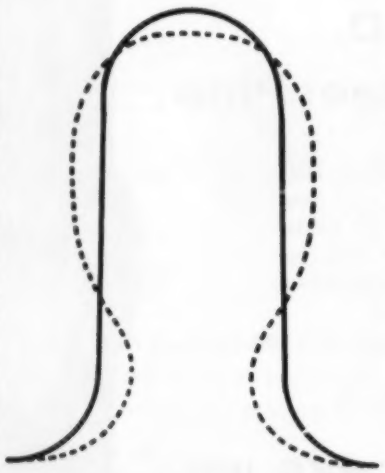

FIGURE 1—Contour of corrugated member of the new type expansion joint. Solid line denotes cold; dotted line denotes hot.

As shown in the cross-section of a series 150 joint (Figure 2), the tubular rings make metal-to-metal contact only in the "valley" of each corrugation. This design maintains the hoop dimension of each corrugation and allows it to assume an "all-curve" shape (dotted line Figure 2) when under line pressure.

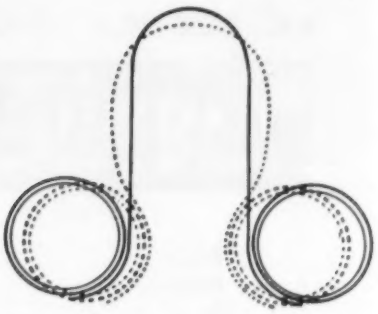

FIGURE 2—Cross-section view of the new type expansion joint showing corrugated member and reinforcing rings. Solid line denotes cold; dotted line denotes hot.

Fabricated from wrought steel, the new reinforcing rings are lighter and can withstand higher pressures and temperatures than conventional cast iron types.

The joints are available in any weldable alloy including stainless steel, Monel, Inconel and nickel for pipe diameters from 3 to 72 inches. They are normally equipped with internal liners which streamline the flow through the joint thereby minimizing turbulence and the high frequency vibrations that result. The internal liners are generally fabricated from the same material as the corrugated member.

The expansion joints are available with either flanged or welding ends. At slight additional cost, all joints may be provided with external covering shields to protect the corrugations from damage and keep them free of foreign materials.

The joints are also available in hinged, tandem or balanced models for installations in pipe lines subject to angular or lateral movement alone or in combination with axial movement. Double joints are available for applications where axial movement is more than can be accommodated by a single joint. Series 50 Joints are also available in rectangular or other custom shapes for special applications. Badger Manufacturing Company.

**Circle E23, green card, last page**

**New Catalogue Describes Services and Products**—The General American Transportation Corporation has just issued its 1957 General Catalogue that describes the services and products that the company and its subsidiaries offer to industrial plants. **Circle E24, green card, last page**

**Control Application Manual**—Thirty-two page illustrated publication explains what each product is, shows how the product works, and tells where the devices can be applied. Two-color bulletin

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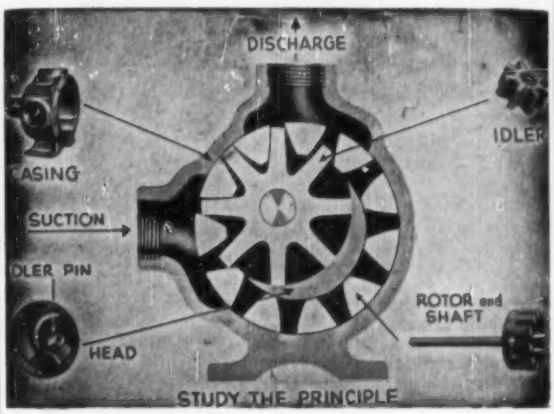
## Viking Operating Principle




Above are illustrated the major parts of the Viking Pump—casing, head, rotor and idler, separately and assembled. Imagine the rotor and idler in motion operating in a counterclockwise direction. Follow the course of the liquid from point of suction to point of discharge. Reverse direction will operate equally well. We invite your inquiries.

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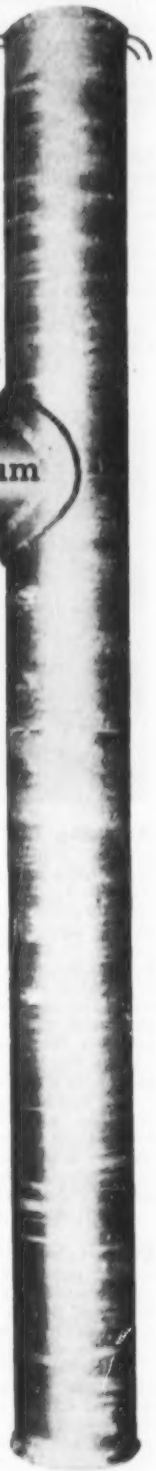

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For more data on advertising products, use Readers' Service Cards, last page.

describes manual, magnetic, and reduced-voltage starters; push buttons; relays; limit switches; solenoids; pressure and vacuum, float, and plugging and anti-plugging switches. General Electric Company.

**Circle E25, green card, last page**

**Calorimeter**—A four page technical data bulletin on their standard water flow calorimeter is now available. The complete unit is manufactured with a sturdy portable cabinet that permits easy carrying but is of such design that the unit can be set up and a test conducted within ten minutes. The bulletin gives illustration and examples of various tests and calculations with the equipment. Sigma Instrument Company, Ltd.

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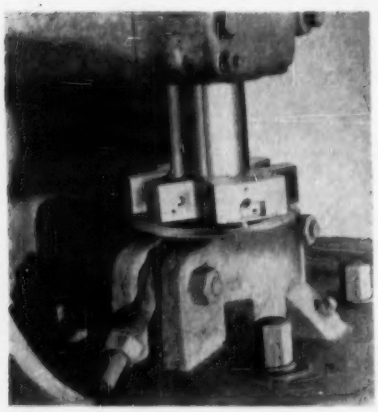


**Refacing Tool**—A new precision hand tool to prepare pump suffingboxes for mechanical seal installation is announced. This stuffingbox refacing tool prepares a smooth gasket surface on the stuffingbox end to assure proper mechanical seal performance. Consisting of a tool bit and holder the refacing tool machines the stuffingbox end at right angles to the shaft axis. The tool bit holder mounts on the shaft with the tool bit against the stuffingbox end. The bit is adjusted to the bore and is worked outward by turning the shaft with a Stillson or strap wrench.

The tool is chrome plated and is shipped complete with wrenches and two extra tool bits. It is available in three standard sizes to accommodate shaft sizes from ¾ to 3 inches. Other sizes are available on special order. Byron Jackson Pumps, Inc.

**Circle E27, green card, last page**

**Caustic Soda Guide**—A new 40-page manual entitled *Caustic Soda Engineering and Handling Guide* is now offered gratis. Technical Service Bulletin 102 is a file-size guide for safe handling and storage of liquid caustic soda.

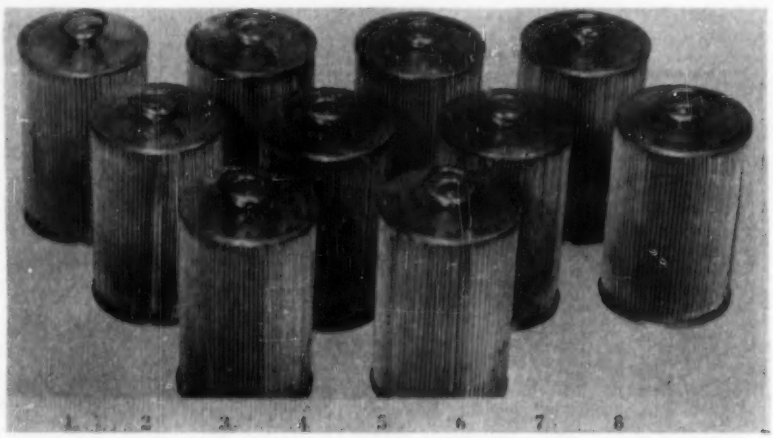
The guide includes large detailed diagrams and photographs of tank cars, piping, and storage equipment, together with recommendations for unloading, dilution, transfer and storage. A portion is devoted to materials of construction, and in addition there is a section on safety precautions and first aid treatment.

The bulletin also contains many graphs, charts, and tables covering physical data on liquid caustic soda. Hooker Electrochemical Company.

**Circle E28, green card, last page**

**Improved Polyester Resin**—Two identical looking samples of polyester resin are actually very different in toughness. After both samples have been thrown with great force upon a concrete floor, the newer sample is undamaged, the other one (of two or three years ago) is shattered. This is a part of the demonstration on the advances of corrosion resistant plastics recently presented at a meeting of the National Association of Corrosion Engineers. The ability to withstand high impact loads as well as chemical corrosion, are combined in these new polyester resins to provide light, strong and tough chemical corrosion resistant equipment. Haveg Industries, Inc.

**Circle E29, green card, last page**



**New Wire Mesh Filters**—The rigidized wire mesh filters are made by furnace welding the wires of the mesh at all contact points. It has plate-like characteristics that permit fabrication by cutting, rolling, corrugating and welding without loss of the original uniformity of mesh openings. Thus, a filter element can be given an accurate, unalterable particle size retention rating. Though the process can be applied to many metals and alloys, stainless steel is generally preferred.

The mesh media are also used in which two or more layers are homogeneously bonded together forming a laminate. In one such type a thin fine facing is bonded to a coarse backing mesh. The assembly combines very fine filtration qualities with high mechanical strength.

Filter elements are stronger, lighter in weight, corrosion and temperature resistant and, most important, reusable. Filters now in operation at temperatures from —65° to 900° and for pressures from vacuum to 10,000 psi service have particle size retention ratings of 2 to 2000 microns. Pall Filtration Company.

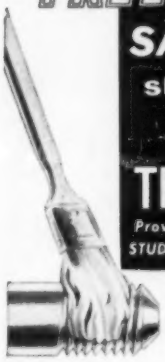
**Circle E30, green card, last page**

**Gilsonite Insulation**—A new four-page, two-color brochure describing gilsonite insulation for hot underground pipes which discusses the problems of underground pipe insulation and explains how gilsulate's special properties overcome them. On-the-job photographs illustrate ease of application; brief technical data are also included. The brochure should prove useful to architects, engineers, contractors, consultants or anyone concerned with the problem of insulating hot underground piping systems. American Gilsonite Company. **Circle E31, green card, last page**

# FREE TEST SAMPLE CAN

shows how C-5 solves "HIGH-TEMP" THREAD PROBLEMS!

*Prove it to your own satisfaction that C-5 ENDS STUD SEIZING AND GALLING EVEN AT 1800°F*



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- √ Ends Stainless "Pitting"
- √ Reduces Torque
- √ Speeds Disassembly

1267

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If you have a pollution or waste recovery problem, a Bulkley, Dunton engineer will be happy to survey your needs and make recommendations. Bulkley, Dunton can also supply a pilot plant for on-the-job tests on your waste flow, if required.

Write today for complete information on Bulkley, Dunton Colloidair Separators or a survey of your disposal problem.

6-248

**Bulkley, Dunton Processes, Inc.**

295 MADISON AVE., NEW YORK 17, N.Y.

# Advertisers in This Issue

## PETROLEUM REFINER, December, 1956

*The asterisk preceding name of advertiser indicates that detailed data on products and services of the firm will be found in The 1956 Refinery Catalog.


Aerovent Fan Co
Large Propeller Division ... 373b
*The Air Preheater Corp. ... 319
*Air Products, Inc. ... 294
Air Reduction Co. ... 318
*Airetool Manufacturing Co. ... 239
Allied Chemical & Dye Corp. ... 66
Allied Chemical & Dye Corp.
Nitrogen Division ... 104
*Allis-Chalmers Manufacturing Co. ... 19, 20, 312-313
*Alloy Steel Products Co. ... 21
*Aluminum Company of America ... 74
American Air Liquide ... 29
*American Brass Co. ... 83
American Cynanamid Co.
Refinery Chemicals Department ... 41
American Gunite Co. ... 346b
American Machine & Metals, Inc. ... 279
American Petroleum Institute ... 250
American Steel & Wire Division
United States Steel Corp. ... 335
Armstrong Cork Co. ... 31
Atlantic Refining Co. ... 354-355
Avondale Marine Ways, Inc. ... 366b

*B-I-F Industries, Inc. ... 129
*The Babcock & Wilcox Co. ... 79
*The Babcock & Wilcox Co.
Tubular Products Co. ... 283
*Badger Manufacturing Co. ... 65, 309
*Bailey Meter Co. ... 97
Barrett Manufacturing Co. ... 346d
Beckman Instruments, Inc. ... 115
*The Belmont Packing & Rubber Co. ... 263
W. H. & L. D. Betz ... 289
Birlec Works ... 76Bb
*Black, Sivalls & Bryson, Inc. ... 82
*Blaw-Knox Co. ... 304
*Blaw-Knox Co., Buflovak Division ... 22
*Borg-Warner Corp. ... 63
Botfield Refractories ... 68
*Bridgeport Brass Co. ... 98
*Brown Fintube Co. ... 286
Bucyrus-Erie Co. ... 62
*Buell Engineering Co. ... 119
*Buflovak Division
Blaw-Knox Co. ... 22
Bulkley, Dunton Processes, Inc. ... 379c
*Byron Jackson Pumps, Inc.
Division Borg-Warner Corp. ... 63

*Calumet & Hecla, Inc. ... 243, 244
Camco Products, Inc. ... 261
The Cape Asbestos Co. ... 77
*The Carpenter Steel Co. ... 103
*Carrier Corp. ... 17
Carter-Waters Corp. ... 349d
Catalin Corporation of America ... 51
Catalytic Construction Co. ... 9
*Catawissa Valve & Fittings Co. ... 255
The Chapman Valve Manufacturing Co. ... 53
Chase Brass & Copper Co. ... 78
Chemical Construction Corp. ... 10
Chicago Bridge & Iron Co. ... 85
*Chikuan Co. ... 23
*Childers Manufacturing Co. ... 6
*Clark Bros. Co. ... 32-33
Classified Advertising ... 356-360
The Colorado Fuel & Iron Corp. ... 248-249
Colton Chemical Co.
Division Air Reduction Co. ... 318
Columbia-Geneva Steel Division
United States Steel Corp. ... 8, 335
The Coniston Co. ... 76D
Cooper Alloy Corp. ... 376
*The Cooper-Bessemer Corp. ... 290-291
*Crane Co. ... 231
*Crane Packing Co. ... 251
Crouse-Hinds Co. ... 256
W. H. Curtin & Co. ... 352a

Davis Engineering Corp. ... 276
De Laval Steam Turbine Co. ... 259
*Delta Engineering Sales Co. ... 308
Dempster Brothers, Inc. ... 340-341
Doerr Glass Co. ... 379b
*Dollinger Corp. ... 26
*Dorr-Oliver, Inc. ... 64
Dowell Incorporated ... 253
*Downingtown Iron Works, Inc. ... 332
*Dresser Industries, Inc. ... 32-33, 330
*The Ducon Co. ... 320
E. I. du Pont de Nemours & Co. ... 120, 277, 278
Durabla Manufacturing Co. ... 372
*The Duraloy Co. ... 315

*E. C. D. Limited ... 76A
*Elliott Co. ... 322
*Engineers & Fabricators, Inc. ... 105
*Ernst Water Column & Gage Co. ... 352b
Ethyl Corp. ... 124-125

Felt Products Mfg. Co. ... 379a
Fischer & Porter Co. ... 285
Fish Engineering Co. ... 295
*Fisher Governor Co. ... 101
*Flexitallic Gasket Co. ... 240
*The Fluor Corp. ... 28

*Food Machinery & Chemical Corp. ... 363
The Foram Corp. ... 366a
Foster Engineering Co. ... 302
*Foster Wheeler Corp. ... 46, 303
The Foxboro Co. ... 273
Frick Co. ... 350b

*The Garlock Packing Co. ... 114
The Girdler Co. ... 113
*Graham Manufacturing Co. ... 301
Graver Tank & Mfg. Co. ... 24-25, 339
A. P. Green Fire Brick Co. ... 59
J. W. Greer Co. ... 50
*Grinnell Co. ... 281
Gulf Publishing Co. ... 76Fb
Gunite Concrete & Const. Co. ... 346c
Gutehoffnungshuette ... 366a

*Hamer Valves, Inc. ... 284
*Hammond Iron Works ... 96
*Harbison-Walker Refractories Co. ... 47
The Harshaw Chemical Co. ... 370
Hercules Powder Co. ... 345
*Homestead Valve Mfg. Co. ... 343
Houdry Process Corp. ... 49
*Hudson Engineering Corp. ... 75

*Ingersoll-Rand Co. ... 292
*International Engineering, Inc. ... 367
The International Nickel Co. ... 311, 365
Isotopes Specialty Co., Subsidiary
Nuclear Corporation of America ... 352c

Jefferson Chemical Co. ... 297
*Jerguson Gage & Valve Co. ... 374a
*Johns-Manville Corp. ... 70, 270a, 351
The Johnston & Jennings Co. ... 254

Kaiser Aluminum & Chemical Corp. ... 80-81
*The M. W. Kellogg Co. ... 86
The C. M. Kemp Mfg. Co. ... 34
Kinney Manufacturing Division
The New York Air Brake Co. ... 305
*Klemp Metal Grating Corp. ... 95
*Koch Engineering Co. ... 109

Ladish Co. ... 56-57
Lapp Insulator Co. ... 67
Lawrence Pumps Inc. ... 338
Layne & Bowler, Inc. ... 87
Layne & Bowler Pump Co. ... 258
Lidell Engineering Service ... 364
*Lincoln Electric Co., Ltd. ... 76Ba
Linde Air Products Co., Division
Union Carbide and Carbon Corp. ... 27, 353
*The Lummus Co. ... 247, 316-317

*The Mack Iron Works Co. ... 349f
Manning & Lewis Engineering Co. ... 245
*Clayton Mark & Co. ... 350a
The Marley Co. ... 371
*Mason-Neilan
Division Worthington Corp. ... 264-265
The Master Electric Co. ... 73
Olin Mathieson Chemical Corp. ... 92
Maywood Chemical Works ... 310b
*A. Y. McDonald Mfg. Co. ... 384
Arthur G. McKee & Co. ... 236
*The Mercoid Corp. ... 274
*Metal Textile Corp. ... 235
Midcontinent Tube Service, Inc. ... 349c
*Minerals & Chemicals Corp. of America ... 67
Minneapolis-Honeywell Regulator Co. ... 333
Misco Fabricators, Inc. ... 344
W. K. Mitchell & Co. ... 39
*Mixing Equipment Co. ... 122
Moncrief-Lenoir Mfg. Co. ... 352d
*Murray Iron Works Co. ... 324

*National Airoil Burner Co. ... 272
National Aluminate Corp. ... 37
National Lead Co. ... 13
National Tube Division
United States Steel Corp. ... 335
Nederlandsch Verkoopkantoor voor
Chemische Producten N. V. ... 76G
New England Tank & Tower Co. ... 326
New England Valve Corp. ... 84
The New York Air Brake Co. ... 305
Newalls Insulation Co., Ltd. ... 76
Newport News Shipbuilding & Dry Dock Co. ... 369
*The C. W. Nofsinger Co. ... 296
*Norton Co. ... 42-43
Nuclear Corporation of America ... 352c

The Okonite Co. ... 99
*Orbit Valve Co. ... 91

Pacific Tube Co. ... 275
Palmer Thermometers, Inc. ... 237
*Panellit, Inc. ... 107

Tod Pazdral Pipeline Specialties ... 329
*Peabody Engineering Corp. ... 328
Perkin-Elmer Corp. ... 90
The Permutit Co. ... 300
*Petreco Division
Petrolite Corp. ... 116
*Petro-Chem Development Co. ... 383
*Phelps Dodge Copper Products Corp. ... 14-15
Philadelphia Gear Works, Inc. ... 18
Pittsburgh Corning Corp. ... 106
Pittsburgh Lectrodryer Corp. ... 260
Podbielniak, Inc. ... 233, 271
*H. K. Porter Co. ... 60, 257, 353
*Posey Iron Works, Inc. ... 375b
The Wm. Powell Co. ... 72
Procon Incorporated ... 327
Puget Sound Fabricators, Inc. ... 373a
The Pyle-National Co. ... 242

The Quaker Oats Co. ... 110
Quaker Rubber Division
H. K. Porter Co. ... 60

*The Refinery Catalog ... 76H, 88-89
The Refinery Engineering Co. ... 44
*Geo. P. Reintjes Co. ... 349b
*Revere Copper & Brass Incorporated ... 229
Reynolds Metals Co. ... 45
Rhodia, Inc. ... 288
The Ridge Tool Co. ... 54
*Rockwell Manufacturing Co. ... 93, 94
*Rockwood Sprinkler Co. ... 11, 337
Roots-Connersville Blower Division
Dresser Industries, Inc. ... 330
St. Mary Iron Works ... 377b
*Sarco Company ... 131
Schott Brothers Co. ... 349a
*Scovill Manufacturing Co. ... 100
*Selas Corporation of America ... 102
Service Foundry, Division
Avondale Marine Ways, Inc. ... 366b
Shand & Jurs Co. ... 325
Shaw-Petrie Ltd. ... 76E
Shell Oil Co. ... 58
*Sier-Bath Gear & Pump Co. ... 336
*M. B. Skinner Co. ... 346a
Nowery J. Smith Co. ... 270a
Solvay Process Division
Allied Chemical & Dye Corp. ... 66
Southern Engine & Pump Co. ... 377c
Stone & Webster Engineering Corp. ... 347
*Strahman Valves, Inc. ... 310a
*Sun Shipbuilding & Dry Dock Co. ... 314
Sunvic Controls Ltd. ... 76Fa

*Taylor Instrument Companies ... 55
Tennessee Coal & Iron Division
United States Steel Corp. ... 8, 335
Tennessee Corp. ... 252, 375a
*The Terry Steam Turbine Co. ... 108
*Texas Metal Fabricating Co. ... 238
Thermal Research & Engineering Corp. ... 342
Arthur Tickle Engineering Works ... 377a
The Timken Roller Bearing Co. ... 35
Titeflex, Inc. ... 71
*Tube Turns, Inc. ... 111, 112
*Tubular Products Division
The Babcock & Wilcox Co. ... 283
Tulsa Gauge & Instrument Co. ... 349e

*Union Asbestos & Rubber Co. ... 323
*Union Carbide and Carbon Corp. ... 27
United States Gasket Co. ... 263
United States Gauge Division
American Machine & Metals, Inc. ... 279
U. S. Hoffman Machinery Corp. ... 267
United States Steel Corp. ... 8, 36, 61, 335
United States Steel Export Co. ... 8
United States Steel Supply Division
United States Steel Corp. ... 8, 335
*Universal Atlas Cement Co. ... 36
Universal Oil Products Co. ... 30, 298-299

Visco Products Co. ... 7
*Henry Vogt Machine Co. ... 48
*J. H. H. Voss Co. ... 374b
Vulcan Engineering Division
Vulcan Copper & Supply Co. ... 269

*W-S Fittings Division
H. K. Porter Co. ... 257
Wagner Electric Corp. ... 262
Walworth Co. ... 38
Warren Petroleum Corp. ... 1
Wedgeplug Valve Co. ... 40
G. & J. Weir Ltd. ... 76C
Western Supply Co. ... 52
*Weston Electrical Instrument Corp. ... 114, 261
Westvaco Mineral Products Division
Food Machinery & Chemical Corp. ... 363
The Whitlock Manufacturing Co. ... 321
Wickwire Spencer Steel Division
The Colorado Fuel & Iron Corp. ... 248-249
*Wolverine Tube Division
Calumet & Hecla, Inc. ... 243, 244
*Worthington Corp. ... 12, 264-265, 348
Wright Chemical Corp. ... 293

*Yarnall-Waring Co. ... 2
*Otto H. York Co. ... 16

*Zallea Brothers ... 307

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| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| E1 | E2 | E3 | E4 | E5 | E6 | E7 | E8 | E9 | E10 | E11 | E12 |
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| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 |
| 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 |
| 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 76 | 76A | 76B | 76Ba | 76Bb | 76C | 76D | 76E | 76F | 76Fa | 76Fb |
| 76G | 76H | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 |
| 95 | 96 | 97 | 98 | 99 | 100 | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 | 111 | 112 | 113 | 114 |
| 115 | 116 | 119 | 120 | 122 | 124 | 125 | 201 | 202 | 203 | 204 | 205 | 206 | 207 | 208 | 209 | 210 | 211 | 212 | 213 |
| 217 | 221 | 225 | 229 | 231 | 233 | 235 | 236 | 237 | 238 | 239 | 240 | 241 | 242 | 243 | 244 | 245 | 247 | 248 | 249 |
| 250 | 251 | 252 | 253 | 254 | 255 | 256 | 257 | 258 | 259 | 260 | 261 | 262 | 263 | 264 | 265 | 267 | 269 | 270 | 270A |
| 270B | 271 | 272 | 273 | 274 | 275 | 276 | 277 | 278 | 279 | 281 | 283 | 284 | 285 | 286 | 287 | 288 | 289 | 290 | 291 |
| 292 | 293 | 294 | 295 | 296 | 297 | 298 | 299 | 301 | 302 | 303 | 304 | 305 | 307 | 308 | 309 | 310 | 310A | 310B | 311 |
| 312 | 313 | 314 | 315 | 316 | 317 | 318 | 319 | 320 | 321 | 322 | 323 | 324 | 325 | 326 | 327 | 328 | 329 | 330 | 331 |
| 332 | | 334 | 335 | 336 | 337 | 338 | 339 | 340 | 341 | 342 | 343 | 344 | 345 | 346 | 346A | 346B | 346C | 346D | 347 |
| 348 | 349 | 349A | 349B | 349C | 349D | 349E | 349F | 350 | 350A | 350B | 351 | 352 | 352A | 352Ab | 352Ac | 352Ad | 353 | 354 | 355 |
| 356 | 357 | 358 | 359 | 360 | 361 | 363 | 363A | 363B | 365 | 366 | 366A | 366B | 367 | 369 | 370 | 371 | 372 | 373 | 373A |
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| 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 |
| 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 |
| 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 |
| 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 76 | 76A | 76B | 76Ba | 76Bb | 76C | 76D | 76E | 76F | 76Fa | 76Fb |
| 76G | 76H | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 |
| 95 | 96 | 97 | 98 | 99 | 100 | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 | 111 | 112 | 113 | 114 |
| 115 | 116 | 119 | 120 | 122 | 124 | 125 | 201 | 202 | 203 | 204 | 205 | 206 | 207 | 208 | 209 | 210 | 211 | 212 | 213 |
| 217 | 221 | 225 | 229 | 231 | 233 | 235 | 236 | 237 | 238 | 239 | 240 | 241 | 242 | 243 | 244 | 245 | 247 | 248 | 249 |
| 250 | 251 | 252 | 253 | 254 | 255 | 256 | 257 | 258 | 259 | 260 | 261 | 262 | 263 | 264 | 265 | 267 | 269 | 270 | 270A |
| 270B | 271 | 272 | 273 | 274 | 275 | 276 | 277 | 278 | 279 | 281 | 283 | 284 | 285 | 286 | 287 | 288 | 289 | 290 | 291 |
| 292 | 293 | 294 | 295 | 296 | 297 | 298 | 299 | 301 | 302 | 303 | 304 | 305 | 307 | 308 | 309 | 310 | 310A | 310B | 311 |
| 312 | 313 | 314 | 315 | 316 | 317 | 318 | 319 | 320 | 321 | 322 | 323 | 324 | 325 | 326 | 327 | 328 | 329 | 330 | 331 |
| 332 | | 334 | 335 | 336 | 337 | 338 | 339 | 340 | 341 | 342 | 343 | 344 | 345 | 346 | 346A | 346B | 346C | 346D | 347 |
| 348 | 349 | 349A | 349B | 349C | 349D | 349E | 349F | 350 | 350A | 350B | 351 | 352 | 352A | 352Ab | 352Ac | 352Ad | 353 | 354 | 355 |
| 356 | 357 | 358 | 359 | 360 | 361 | 363 | 363A | 363B | 365 | 366 | 366A | 366B | 367 | 369 | 370 | 371 | 372 | 373 | 373A |
| 373B | 374 | 374A | 374b | 375 | 375A | 375B | 376 | 377 | 377A | 377Ab | 377Ac | 379 | 379A | 379B | 379C | | | | |

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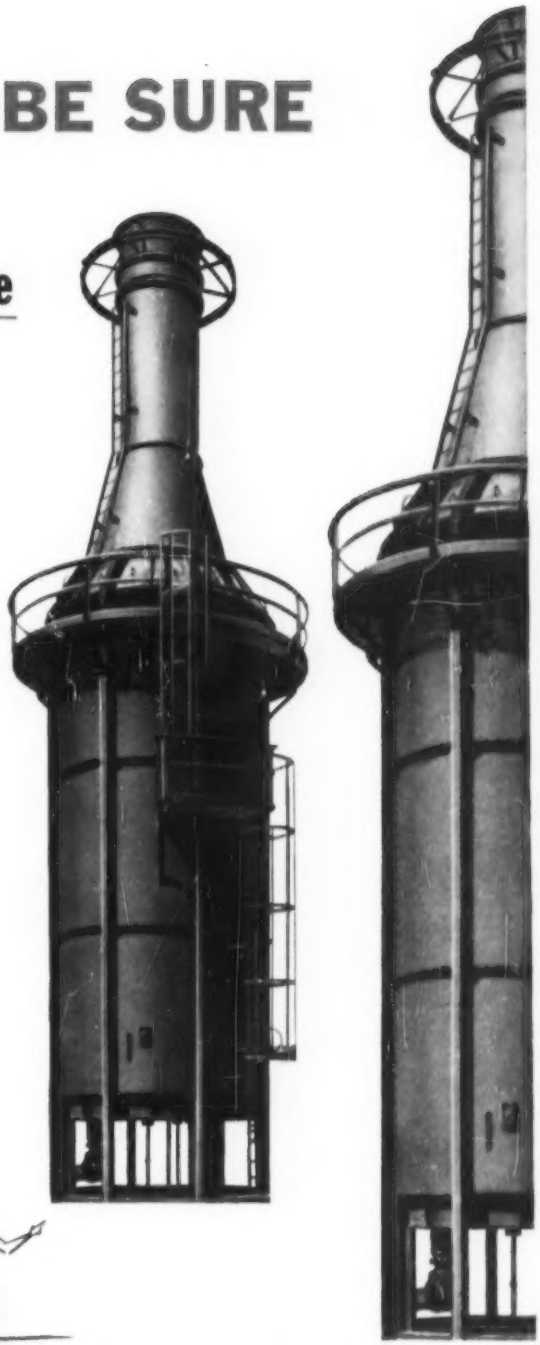

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6—Controlled thermal recirculation of flue gases to provide even heat distribution throughout full length of each tube and equalized heat distribution around each tube.
7—Overload and corresponding transfer load.
8—Design to provide: structural column supports—Ladders—Platforms—Tube Removal facilities, etc.
9—Degree of assembly; of the furnace structure and of the heating surface.

*When you specify PETROCHEM-ISOFLOW FURNACES ... you'll be in good company. More than 1500 are now in service, performing to the complete satisfaction of their operators and usually well beyond their rated capacities.*

**PETROCHEM-ISOFLOW FURNACES**

UNLIMITED IN SIZE ... CAPACITY ... DUTY

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*Dependable Efficient*

# McDonald Oil Equipment

*Backed by a century of experience*

Over 100 years of successful manufacturing experience back each item in McDonald's oil equipment line. Top quality materials, the most modern equipment, superior design and expert craftsmen combine with McDonald's century of experience to give you equipment with the utmost in dependability and efficiency. Specify McDonald and be sure.

Plate 214, Size, 3"

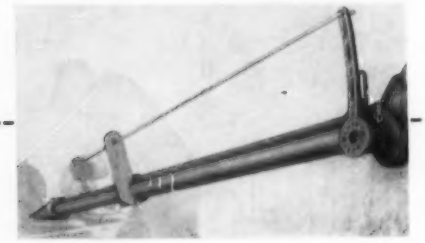
**McDonald Loading Arm Assembly**

Every detail of design in this popular Loading Arm Assembly is directed to a single objective — the highest attainable degree of loading efficiency. Balanced design, with divided counterweights that cannot strike the riser, assure effortless trouble-free operation.

These construction features are your assurance of dependable operation.

- Swing Joint, identical swing joint features as those of the well known McDonald Master Series — concentric design.
- Range, 7 feet closed to 11 feet extended, measured from center line of riser.
- Solderless Joints on entire brass slide sleeve assembly assure easy replacement and stronger construction.
- Bolted Stuffing Box on slide sleeve, easily adjusted and repacked. Oversized bearing area assures easy operation.
- Felt Wiping Gasket, easily replaced, keeps slide tube clean, increases life of the tube and packing.
- Aluminum Outboard Swing Joint, concentric design, drop tube hangs vertically.
- Detachable Handle operates slide sleeve and drop tube.
- Shock-Proof Loading Line Valve, equipped with vacuum breaker.
- Weight, 429 lbs.

Plate 214-R



**Remote Control for Loading Assembly**

Plate 214-R Remote Control furnishes a convenient method for holding open the line valve of Plate 214 Loading Assembly. At the same time, it permits the operator to watch the filling process and have complete control of the valve.

Plate 860-N, Size 4"

**McDonald Flanged Non-Rising Stem Type Expansion Relief Valve**

Provides positive protection from leaks at gaskets and joints which result from excessive pressure caused by expansion. Should pressure build up in the line due to the heat of the sun, for example, the disc in the by-pass of the valve opens to equalize the pressure in the line with that of the tank. Iron body — bronze-faced solid wedge, guided both sides — bronze seats and stem. Weight, 106 lbs.

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**A. Y. McDONALD MFG. CO.**

DUBUQUE, IOWA

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